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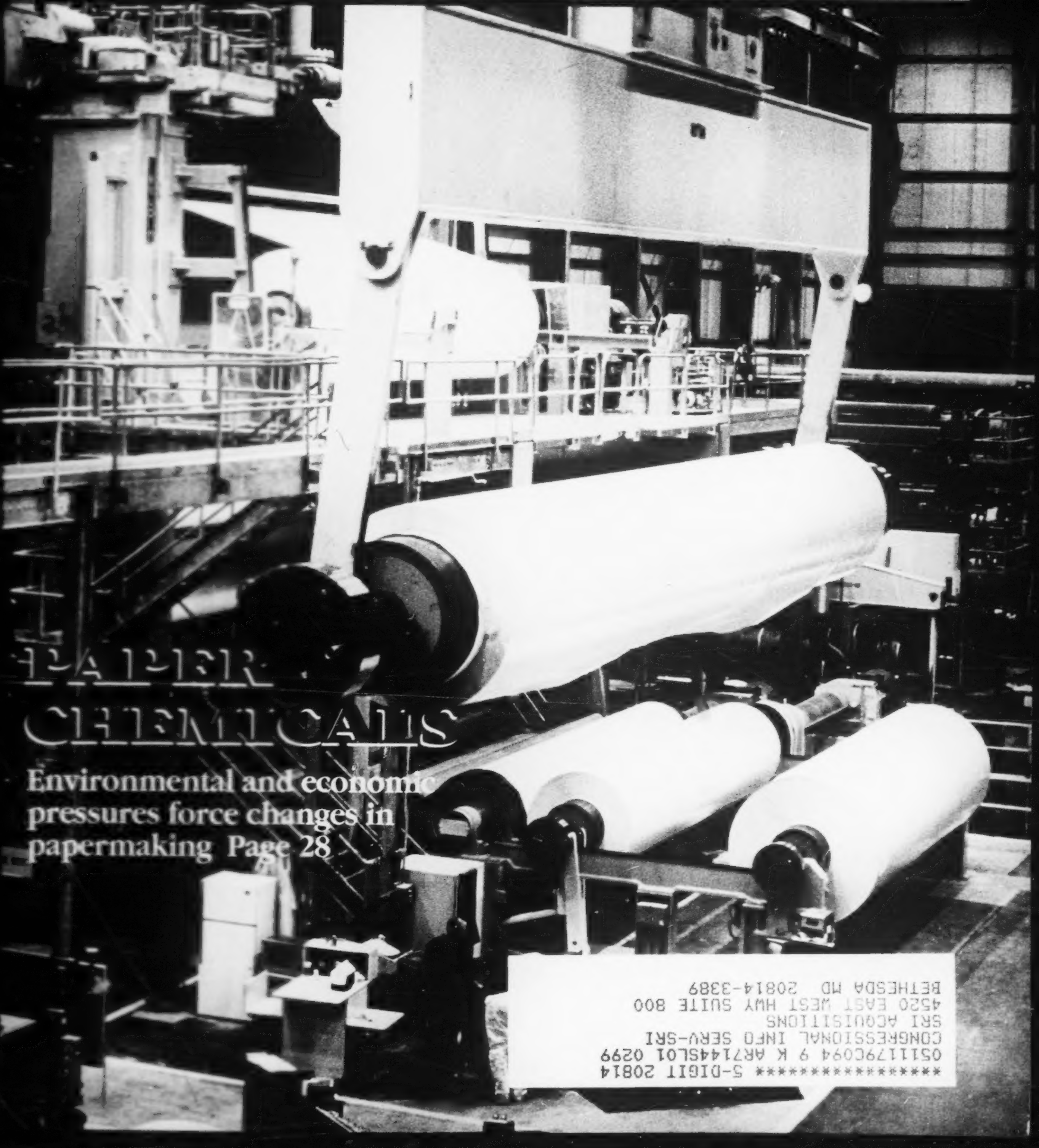
CHEMICAL & ENGINEERING NEWS

C&EN

NOVEMBER 1, 1993

INDUSTRY OFFERS IDEAS TO IMPLEMENT CHEMICAL WEAPONS TREATY PAGE 21



PAPER CHEMICALS

Environmental and economic pressures force changes in papermaking Page 28

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CHEMICAL & ENGINEERING NEWS

C&EN

NOVEMBER 1, 1993

NEWS OF THE WEEK

- AAAS's Project 2061 releases guidelines for what students should know in science, math, and technology at specific points in primary and secondary school. Page 4
- Third-quarter earnings are up for many major chemical producers, as the earnings turnaround that began in the second quarter continues. Page 5
- American Chemical Society sets ambitious plans for National Chemistry Week, Nov. 7–13, including radio morning talk show appearances by ACS president Helen M. Free. Page 5
- CD26, an enzyme found on surface of immune system cells, appears to act in concert with another cell-surface protein, CD4, to enable AIDS virus to invade the cells. Page 6
- First Technology Reinvestment Project grants were announced last week—a total of $140 million will fund 41 proposals. Page 7
- University of Pennsylvania observes centennial of its chemical engineering program, awards distinguished service medals to three chemical engineers. Page 7

COVER: Weyerhaeuser's pulp and paper plant at Columbus, Miss.

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BUSINESS

Covenant between Dutch government and chemical industry calls for major cuts in emissions from plants and other steps to improve the environment to be accomplished by 2010. **Page 11**

European chemical market researchers discuss problems, ways to survive in the current depressed economies at their annual meeting in Madrid. **Page 14**

Touting the virtues of the North American Free Trade Agreement and pushing for its passage is the current mission of Dow Mexico president L. Kip Smith. **Page 16**

Ten U.K. fine chemicals companies complete a U.S. promotional tour that is designed to establish supply relationships with U.S. chemical and drug firms. **Page 19**

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Chemical industry representatives meet with chemical weapons treaty's Preparatory Committee to establish communication channels concerning the pact's implementation. **Page 21**

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Chemistry pioneer Gilbert Norton Lewis is honored by his hometown and state, 47 years after his death, through determined efforts of local retiree. **Page 25**

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Biography of atomic scientist Leo Szilard pays tribute to the eccentric, iconoclastic genius who conceived the nuclear chain reaction and sought measures to control its use. **Page 42**

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ACS award winners: Seaborg, Somorjai, Thomas, Vliegenthart, Walsh, Wankat, Whitesides, Yen, Yeung, Yoder, Zwanzig. **Page 47**

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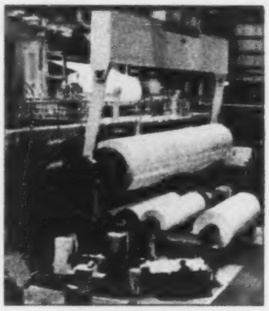

Paper and paperboard comprise a multi-billion-dollar industry that uses vast amounts of natural resources, equipment, energy, and chemicals; but paper chemical suppliers face strong environmental pressures and major changes in their pulp and paper markets. Page 28

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Chemical & Engineering News
1155—16th St., N.W., Washington, D.C. 20036
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Assistant Managing Editors: James H. Krieger, Janice R. Long, Rebecca L. Rawls, Donald J. Soisson, William J. Storck
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LETTERS

Glycoprotein anchors

One of the Science/Technology Concentrates (C&EN, Aug. 30, page 20) describes the synthesis of the anchor linking Thy-1 to cell surfaces [*J. Am. Chem. Soc.*, **115**, 7886 (1993)]. Two points in this summary require clarification.

First, Thy-1 is a protein with a specific class of glycoprotein anchor—a glycosyl phosphatidylinositol (GPI) anchor. This is not common to all cell-surface glycoproteins. GPI anchors were first described by M. W. Stein and C. F. Logan Jr. [*J. Bacteriol.*, **85**, 369 (1963)], and the first complete structure of a GPI anchor (that of the variant surface glycoprotein of *Trypanosoma brucei*) was elucidated by M. A. J. Ferguson, S. W. Homans, R. A. Dwek, and T. W. Rademacher [*Science*, **239**, 753 (1988)]. GPI anchors contain a tetrasaccharide linked glycosidically to phosphatidylinositol. There may be a variety of substituents on the core polysaccharide structure, and the lipid portions of the anchor are also variable.

Second, Thy-1 may be the most thoroughly studied of the mammalian GPI-anchored proteins, but others include human erythrocyte acetylcholinesterase; placental alkaline phosphatase; and the complement regulatory protein, decay accelerating factor. A review of GPI-anchor biosynthesis in these and other proteins has been recently published by P. T. Englund [*Ann. Rev. Biochem.*, **62**, 121 (1993)].

These small points of elaboration in no way diminish the accomplishments of Bertram O. Fraser-Reid and his colleagues. Access to milligram amounts of this structure can only further knowledge of all the others.

Donna J. Carothers
Cleveland Heights, Ohio

MTBE possibly unsafe, useless

The title of the article "Health Studies Indicate MTBE Is Safe Gasoline Additive" (C&EN, Sept. 20, page 9) is misleading. Information in the article does not support the conclusion stated in the title.

Methyl *tert*-butyl ether (MTBE) is added to gasoline under federal mandate to reduce carbon monoxide levels in automobile exhaust. Your article concluded that it is safe to add MTBE to gasoline, because tests show that most people do not suffer obvious harm from inhaling MTBE vapor. However, you presented no test results that would show that the exhaust fumes from a vehicle operating on oxygenated gasoline are "safe." How can any conclusion be drawn about the safety of a fuel additive, whose purpose is to reduce noxious exhaust emissions, unless the combustion products of the fuel are tested?

An earlier issue (C&EN, April 12, page 28) reported that tests in Colorado have shown that use of the oxygenating additive MTBE does not reduce carbon monoxide levels in the environment and actually increases the levels of other more noxious pollutants containing oxygen, such as aldehydes and ketones. These kinds of compounds can be irritants and can cause cancer and respiratory problems. The use of MTBE caused so many health problems in Fairbanks that its use was discontinued there. These problems were probably caused by the combustion products of the fuel, not the fumes from the fuel tank. However, your article indicated that investigations of the problems focused on fumes from the fuel, not on what is produced in the exhaust. The Environmental Protection Agency doesn't look for carbon monoxide coming out of the gas tank; it measures the carbon monoxide coming from the tailpipe. It is inconceivable that EPA didn't check the vehicle exhaust. Perhaps the results were just not made available to or reported by your staff.

What are the hydrocarbon, nitrogen, sulfur, and oxygen compounds in exhaust from cars burning oxygenated fuels? What environmental levels of these compounds result from the use of oxygenated fuel? Are these safer and less noxious than those from normal gasoline? How much is produced per mile of vehicle use? Does it vary with the age of the vehicle or with ambient conditions (as in Alaska)? Good science would answer questions like this in addition to those relating to MTBE fumes.

Your article didn't mention that oxygenated fuel also causes serious problems with automobiles. Last October, with the first tank of oxygenated fuel, my 1987 Pontiac developed a "bucking" condition. When I asked the dealer for an engine tuneup, he said that the transmission

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Dutch Plan Sets Environmental Targets for Chemical Industry

■ ***Pact between industry and government calls for severe reductions in emissions from plants in three stages by 2010***

Patricia L. Layman, C&EN London

Among their European neighbors, the Dutch are well known to be a people of great tolerance. They are also well known as a people who seek consensus in settling national problems or issues. Their latest such effort at consensus, now under way, directly affects the chemical industry.

The Dutch effort is a "covenant"—established between the nation's government and its chemical industry—to move the Netherlands forward in sustainable development, toward the year 2010, by cutting emissions from chemical production at both large and small chemical companies. The agreement is even accepted, in principle, by many of the country's tough environmental groups, although they have serious reservations on such aspects as timing and extent of the efforts.

At present, about 1700 covenants are in force in the Netherlands, on all sorts of subjects. They are part of the country's culture. Whether the Netherlands' experience could ever yield lessons applicable in more confrontation-oriented countries is debatable, although chemical industry associations in other European countries, and CEFIC, the European Chemical Industry Council, have been discussing the subject with their Dutch counterparts. Meanwhile, the experience is a breath of fresh, rational air in the global environmental debate.

In essence, the covenant the Netherlands government has worked out, in discussion with industry, regional, and local authorities, provides a national plan to tackle environmental problems generated during chemical production processes. The chemical industry's plan, now being implemented, is the third, following those covering the primary metals and printing industries last year.

The chemical industry has committed itself to supporting the national plan, which sets forth firm sectoral goals for 2000 and targets for 2010. The government, in turn, has pledged to not unilaterally change its standards or requirements during this time. The Dutch government thereby achieves its strategic goals of lessened environmental pollution. And the industry's managers can incorporate the goals into their long-term investment planning.

The national plan for the chemical industry was signed in The Hague in April, and the industry was given until September to digest its content and begin working on individual company plans. Each company will write a plan for each plant site, contributing toward reduction of process pollution. Companies have now begun working on these plans, which are scheduled for completion and for presentation to the government in 14 months, according to Willem Quik, technical director at the Association of the Dutch Chemical Industry, VNCI (Vereniging van de Nederlandse Chemische Industrie), in Leidschendam, just outside The Hague.

As VNCI pointed out when the agreement was signed by the parties, to realize the aims of the covenant, the chemical industry will have to invest more than 10 billion guilders—roughly $5.7 billion—from 1993 to 2000. The starting premise was that environmental measures must be technically and economically feasible, as the industry works to meet the industrywide targets set in the national environmental plan. This has led to compilation of an "emissions profile" detailing emissions in the base-year 1985 by the chemical industry.

The chemical industry will gear its policy to implementing the plan in three phases: the first running until 1995; the second, to 2000; and the third, to 2010. All aspects of environmental policy have been included: not only emissions into water, soil, and air, but also energy savings, reduction of process wastes, soil decontamination, external safety, odor and noise nuisance, and internal corporate environmental management systems.

The agreement also provides for

NIEUWSPOORT

Environmental covenant being signed earlier this year by Ruud Selman, who was president of VNCI at the time, as government and other officials looked on streamlining and coordinating the activities of the various public authorities. Central government, the provinces, the municipalities, and the water boards—historically, the earliest Dutch regulatory bodies dating back to the 13th century—are to begin working together more closely, so chemical companies will be able to count on more uniform policy.

However, as Quik points out, the covenant covers only the impact of production processes, not of products themselves. Targets for waste reduction, for example, are process wastes, not post-consumer waste.

Reductions are taken from 1985 levels, the base year. "The year 2000 is a solid goal," Quik said, and 2010 is a "guidance" goal. "We assume there will be technology improvements by that time, because we need them to get those [environmental] improvements. We will see, closer to that time, whether we need to modify the targets up or down."

Cees Moons, director of the industry division in the Directorate General for Environmental Protection in the Ministry of Housing, Physical Planning & Environment at The Hague, said the whole process started when a document was issued by the National Institute of Public Health & Environment, called "Concern for Tomorrow," which outlined steps toward a sustainable future. This was in the same wave of movement as the efforts in the late 1980s spearheaded by Norway's Prime Minister Gro Harlem Brundtland, Moons said at a roundtable discussion of the covenant at the VNCI, which included Moons, Quik, and Jan-Willem Biekart, who is with the Stichting Natuur en Milieu, the Foundation for Nature & the Environment.

The Dutch document led to the National Environmental Policy Plan, "To Choose or to Lose," issued in 1989. This document was discussed in Parliament, which agreed on the targets in the plan. These targets were then formulated into a plan to put into effect.

"Then we faced the question of how to execute this plan," Moons said. "We saw two extremes as possibilities to implement the plan," he explained. The government could go just with voluntary agreements with covenants, instead of legislation, or it could go with legislation alone, traditionally the more usual way. "We decided to make a combination of the two. The implementation should be done on a legal basis, to not only give obligations to the companies, but rights and certainties about investments." The law already requires a site to have an operating license, which is subject to negotiation, he pointed out. The covenant would ensure agreement, rather than conflict, and it would give companies a plan to use as a management tool.

Dutch chemical industry at a glance

Sales in 1992: **$24.6 billion—15% of country's industrial production**

Sales makeup: **bulk chemicals, 60%, and specialty chemicals, 40%. Sales to European Community, 72%; U.S., 4%; Japan, 2%; and others, 22%**

Exports in 1992: **$24.1 billion—20% of country's total exports**

Imports in 1992: **$15.4 billion**

Capital spending in 1992: **$1.9 billion—25% of country's industrial investment**

Production index (1985 = 100): **1991 = 120; 1992 = 122**

Employment in 1992: **87,400—10% of country's total industry employment**

Starting with the most serious priorities, the government began the discussion process with two branches of industry—primary metals and chemicals—looking with each at the problems peculiar to that branch. The sessions included representatives from the relevant ministries, municipalities, provinces, water boards, and industry federations.

It was important, Moons emphasized, that all the groups be represented, particularly the provinces and municipalities. "At the end of the process, the results should be laid down in the licenses," he said. "Therefore, we must have commitment from the provinces and municipalities, because they are the ones who grant the licenses. Much negotiation still has to be done at the level of the individual company, but by the covenant there is a framework, so we can see if results are good or not."

And, he added, "it was not an easy process. A good covenant should not be signed too easily. When it has meaning," and people must make a serious commitment, "there should be hesitation in signing it." Moreover, there were some complications from the fact that the first covenant, for the primary metal industry, was held to be the framework for all the remaining industrial sectors. "It did complicate matters for the chemical industry just a bit," acknowledged Moons, "but not too much."

According to VNCI's Quik, "Going through a negotiating process for two-and-a-half years was not time lost. We were creating commitment, and [gaining an] understanding of what the plan meant. We have about 95% support from our members. Had we signed in a month, we would have had more difficulty getting everybody on board."

The Foundation for Nature & the Environment's Biekart brought up the environmentalists' qualms. "Not all that time has been used to gain support from chemical industry," he said. "There was lots of time lost in debating commas and points in the text—that's what [environmentalists] think. And much more time will probably be lost in the future without real action being taken."

He granted that the chemical industry's support for the plan "has been greater than for that of the primary metal industry. You have talked more with your industry," he said to Quik. But Biekart observed that in practice many local governments are saying that, because of the negotiations with companies, they will defer writing new, tougher licenses until the covenant is completed, and they will sharpen the requirements then. "The longer the negotiation, the longer it takes before licenses start to be sharpened—it may be more than a year. Time is an important criterion for us—every year's delay is a year too much for us."

According to Moons, the time taken was the shortest time practicable. The government first had to work out its text, then gain commitment from the industry. Next came the time for discussing provisions of the covenant with provinces and regions. Additionally, the large number of companies in the chemical industry prolonged the time needed. "For the primary metal industry," he pointed out, "one company in particular, Hoogovens, is by far the biggest out of a total of maybe 20 or 30 companies. Hoogovens was willing to sign, to take the lead, and the smaller ones would follow."

The primary metal industry companies were given eight months to develop their individual corporate plans. Based on the government's experience there, it lengthened the time for chemical companies to 14 months. Besides, he says, "when we get 140 plant site plans, we couldn't do them all at once." And the government is working on plans for the other industries, for a total of eight. The covenant for the printing industry is now signed, and that for the dairy industry is coming up. The covenant for the electronics industry will be finished by the end of this year, while negotiations have started on covenants for the paper, textiles, and meat industries.

The extended time, though, does not please environmentalists. Biekart insisted: "There are a number of examples of licensing being stopped while authorities are waiting. At first, it was only eight months until every signing company would have a site environment plan. Now that has stretched out to 14 months. The time becomes longer and longer, but the results are not certain. We have only the commitment—which is worth a lot, but is not a fact, and does not give a firm grip on the outcome of the process."

Industry had to have time to work out how it can hold up its end of the covenant bargain, Moons responded. "If you look at the year 2010, you must look at process modification and integration. You can't reach the targets with end-of-pipe solutions. You must combine a process-integrated solution with investment plans. Therefore, it must be an open process, with the company supporting the effort. It takes time to do this."

Part of the problem as Biekart sees it, however, is the very nature of those commitments. Although the covenant "in some aspects is very valuable," he acknowledged, "we doubt the commitment. We don't trust industry because we've never had grounds to do so. If companies did these things over the last 10 years, it is because authorities forced them to, it has not been their choice. We want to see that industry commits itself to sustainable development, and that it devotes its creativity to reaching this goal."

And he indicated just a bit of longing for confrontational legal battles. "Our basic criticism is that we are absolutely unsure about what will come out of the effort. Self-regulation is becoming a huge issue. In the U.S., you can ask a judge to clarify the case. In the Netherlands, we have only an administrative judge. We miss the fighting capacity: the [Dutch culture requires] talking, finding agreements, compromising, being reasonable.

"In this, if government gives away any part of its legal position, it is giving away the environment," Biekart said.

"No one is giving away any legal position," Moons answered. Moreover, he sees improvements from the current situation: Environmental groups will get more information, and things will get better.

For Quik, the plan offers no guarantee to the industry. "If you have a guarantee, you would also get a guaranteed license to operate. But we won't—we will still have to get permits, and we might not be able to. The system is reasonably in balance."

Nonetheless, Biekart said, the government "should not be afraid to introduce policy measures stronger than these commitments. I'm not against the covenant—I'm fully aware of the value of this. On the other hand, there are pressing environmental problems, and not just problematic emissions of substances like sulfur dioxide and nitrogen oxides. We think it's necessary to introduce stricter instruments alongside these covenants—a carbon [energy] tax, controls on use of groundwater, and so on."

Such measures are outside the scope of the covenant, and could be more transnational, as well. Meanwhile, VNCI members are now working out how to cope with the covenant. There are two levels of commitment—one by the chemical industry, for which the VNCI signed, and one by the individual companies.

Key reduction targets set by Dutch environmental plan

	2000	2010
	(% reduction from 1985)	
AIR EMISSIONS		
Benzene	75%	97.5%
Acrylonitrile	50	97
Ethylene	50	90
Toluene	50	90
Vinyl chloride	90	90
Fine particulates	75	95
WATER EMISSIONS		
Benzene	75	90
Acrylonitrile	50	90
Oil	60	90
Nickel	50	80
Zinc	65	80
Lead	65	70
Nitrogen compounds	70	75
Phosphorus compounds	75	90

Source: Declaration of Intent on the Implementation of Environmental Policy for the Chemical Industry

VNCI has about 105 members, of whom about 95 have signed the covenant, covering more than 95% of the industry's emissions. According to Quik, some members have not signed the covenant but will form a plan—some of these might be companies already in legal battles over pollution guidelines, for example, who would not want to prejudice their cases.

Some of the subsidiaries of U.S. companies have signed; others are cautious about signing, but will adhere to the covenant nonetheless. If a company offers no cooperation at all, local authorities can take the initiative to change—by strengthening or even refusing to issue—a license. Quik predicted that ultimately only 1 to 2% of VNCI's members will not voluntarily cooperate.

He said, "We have already told our members that if they run into difficulties with licenses and have not signed, we will find it difficult to support them, at least officially."

The targets in the government plan are based on agglomerated data for the chemical industry. Companies make their plans based on best available technology, and it is up to the government to look at the sum of the plans, to ensure that the totals are approaching the country's goals. Plans are open to public inspection and include an annual progress report.

According to Biekart, this is undoubtedly an improvement, as far as environmentalists are concerned. "It gives us all opportunities, and gives an opportunity to industry itself. This will make it clear: who is far in front, who is behind. It is still to be seen what will be in these plans. For us, this is a minimum only, particularly because the plans are only for production."

Quik said, "For all parties, this is a learning process. The plan is very challenging, particularly in a time of economic downturn." He added, "We think this covenant will be an advantage because it will give companies flexibility. Companies know what they're heading for, given the long-term objectives. You can build accordingly. This gives companies a framework for priorities." ☐

PRODUCT REPORT

PAPER CHEMICALS

Paper chemical suppliers face strong environmental pressures, major changes in pulp and paper markets

Ann M. Thayer,
C&EN Northeast
News Bureau

Because paper is ubiquitous, it generally is taken for granted. However, paper and paperboard comprise a massive, multibillion-dollar industry employing vast amounts of natural resources, equipment, energy, and chemicals. The U.S. paper industry, with a positive trade balance, has long enjoyed a competitive advantage over competing industries in Scandinavia, other countries in Europe, and Japan.

However, the outlook for profitability in the industry has been bleak since 1991, when earnings plunged almost 25% below 1990's already depressed earnings. In 1992, profit margins for pulp were near zero, and U.S. shipments of paper and allied products grew only 1.5% to more than $126 billion, according to the Department of Commerce. The market continues to be constrained by declining prices, overcapacity, and generally poor world economies. Modest volume growth is expected to continue, with paper shipments growing about 4% in 1993 and continuing to grow about 2.5% per year through 1997.

Papermaking is being affected by federal, state, and local regulations regarding solid waste, air and water quality, and government procurement. Numerous environmental and business groups specifically are targeting the industry to change its production methods, its chemical use, its energy consumption, and its environmental impact. And several pieces of federal legislation—among them the Clean Air Act and the Clean Water Act—are expected to directly affect papermaking through new emissions standards.

Environmental and economic pressures, along with shifting consumer demands, have been changing the way paper is manufactured. However, many industry observers say that, at a time when the paper industry is so depressed, papermakers have been slow to capitalize process and equipment changes, taking these steps only when they have been absolutely necessary. Pulp and paper industry capital spending was down about one third from a record level of 1990 to $11.3 billion in 1992, says Commerce, with environmental capital spending accounting for 11 to 12% of the total.

Still, major changes have been occurring in the chemistry of each step of the papermaking process, leading most chemical suppliers to a more positive outlook than their paper industry customers. Changes arising from concerns over paper mill effluents, recycled paper content, and conversions from acid to alkaline papermaking generally are pushing an overall growth rate in many chemicals to at least twice that of the paper industry.

The market for pulp and paper chemicals is estimated to total more than $4 billion, or about $100 worth of chemicals for every ton of pulp produced. Demand for pulp and paper chemicals is expected to grow 6% annually to $4.8 billion in 1995, according to the Cleveland-based marketing research firm Freedonia Group. However, the greatest barrier for chemicals will be any related capital costs for new processes.

Papermaking elements

However large and complex the papermaking process and industry are, most of their constituent elements are represented in a single sheet of paper. The basis of most paper is wood fibers from pulp produced by chemical or mechanical means, or a combination of the two, depending on the desired grade of paper. Pulp production, often using large amounts of caustic soda ($NaOH$), is only the first in a several-step process involving myriad commodity and specialty chemicals.

Elf Atoch

Paper rolls await shipment at completion of papermaking process

The pulp used to form a sheet of paper also may include fibers from recycled paper—either paper mill scrap or consumer waste. The recycled paper content is expanding primarily because of concerns about the disposal of municipal solid waste. In 1992, 33.6 million tons, or more than 38% of paper and paperboard production, were recovered for recycling or export. Of this recovered amount, 26.2 million tons made up 30% of pulp raw materials used in new production, according to figures from the Washington, D.C.-based American Forest & Paper Association.

In 1993, the amount of paper recovered is expected to reach 36.7 million tons, with 29 million tons reused domestically. The U.S. paper industry has set a goal to recover 40% of all paper used by 1995. As the recycled content of paper increases—and the presence of weakened reprocessed fibers—so too does the need for new chemistries and processing chemicals. To use these secondary fibers, many different chemicals are needed to remove inks, to bleach, and to separate out the nonfiber components of recycled paper.

Whatever the source, fibers usually are bleached in the next step of the papermaking process if they are to be used in high-grade paper applications. The most common bleaching chemicals are chlorine and chlorine dioxide. However, moves away from chlorine chemicals because of environmental pressures on the control of 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (2,3,7,8-TCDD) and chlorinated organics in paper mill effluents are increasing the use of other bleaching agents such as hydrogen peroxide, oxygen, or ozone.

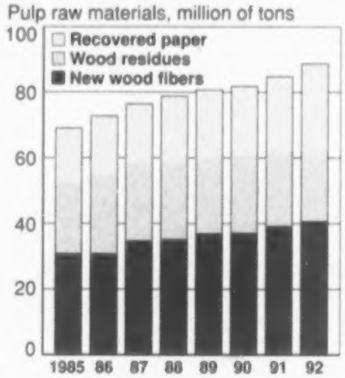
To replace expensive pulp, as well as provide opacity and dimensional stability, the clean fibers may be mixed with mineral fillers and pigments such as calcium carbonate, kaolin, or titanium dioxide. Binders and sizing materials such as latexes, starch, rosin, and synthetic polymers retain the fillers or add water repellency, a useful property for printing with water-based inks.

Processing aids—primarily polymer based—that increase fiber retention and drainage, or contribute wet or dry strength, are added before a sheet of paper is formed. The fiber and chemical mixture is then laid out on a wire mesh to allow for water drainage, pressed, dried, and generally mechanically finished.

Coatings, again often mineral-based, also may be used to give paper its finished appearance, such as on this sheet of magazine paper. A desire for lower weight papers, to decrease shipping and postal costs, and an increase in the use of four-color printing are expanding the use of coatings to ensure the opacity of thinner sheets and the finish required for color printing. Depending on the application, other polymer or wax coatings may be applied to paper for moisture resistance.

The most significant chemically related change in recent years has been a move from acid to alkaline papermaking, which has spurred growth for specialty chemicals and fillers. Acid or alkaline refers not to the pulping process, but rather to the residual pH of the paper at the time a sheet is formed. Alkaline paper is valued more because it lasts longer, is less susceptible to yellowing, and allows for greater amounts of pulp-replacing fillers. The majority of paper in the U.S. now is produced under alkaline conditions.

Recovered paper adds to pulp raw materials



Source: American Forest & Paper Association

Pulp chemicals market to grow

The goal of pulping is to reduce wood to cellulose fibers while removing lignin, a natural resinous adhesive. Pulp produced from hardwoods (deciduous trees) tends to have shorter, weaker fibers, compared with that from softwoods (coniferous trees). Traditional mechanical or chemical, or newer combinations such as thermomechanical or chemothermo-mechanical, processes can be used to produce pulp. Mechanical, also called groundwood, methods produce extremely high yields of less pure and less expensive pulp, used extensively in newsprint. Although the yields are lower, by about 50%, chemical pulping methods produce a much cleaner, stronger pulp.

In simple terms, chemical pulping can be divided into processes based on caustic soda and sulfates, or sulfites. Sulfite pulping involves boiling wood chips in an acidic solution. In the kraft process, also called the sulfate process because of the addition of sodium sulfate to aid in digestion of the pulp, wood chips are heated in a caustic liquor. More than 80% of pulp made in the U.S. is from the kraft process. As the strongest pulp, unbleached kraft pulp commonly is found in corrugated cardboard and paper bags.

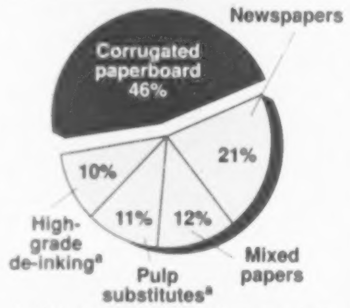
Kraft pulping also is attractive because it is more energy efficient than other processes, and it can be operated in a closed loop in which almost all of the caustic soda is recovered. However, the kraft process, as well as other pulping methods, has come under environmental scrutiny because of emissions and effluents, toxic residues or materials that must be disposed of, or the need to further bleach the pulp.

Traditionally, pulp and papermaking companies have been major customers for chlorine and caustic soda, coproduced by an electrolytic process that yields 1.1 tons of caustic soda for each ton of chlorine. Consequently, papermakers have become known as electrochemical unit—ECU—buyers. Major chlor-alkali producers include Dow Chemical, Occidental Chemical, Georgia Gulf, Olin, PPG Industries, and Elf Atochem.

The paper industry is the single largest market for caustic soda, accounting for about one quarter of total production. Caustic soda use in the industry is expected to grow very slowly over the next five years, about 1% or so per year, says Roger E. Shamel, president of Consulting Resources, Lexington, Mass., from the present level of about 2.7 million tons per year. However, the simultaneous shift away from chlorine as a pulp-bleaching chemical is expected to contribute to a chlor-alkali imbalance within the paper industry, on top of the already cyclical chlor-alkali markets.

Chlorine, which follows the general economic cycle, currently is expensive, explains Shamel, and caustic soda, which lags the cycle by six months or so, is relatively cheap—a situation that was reversed only a year ago. ECU buyers generally receive more favorable pricing in buying both coproducts. And, although ECU buyers are nearly ideal, stable customers for chlor-alkali producers, the situation is not expected to continue as a higher ratio of caustic to chlorine becomes needed by the paper industry.

Paperboard is 46% of recovered paper wastes



1992 total recovered paper and paperboard = 33.6 million tons

[a] Includes ledger, tabulating cards, bleached sulfate paper shavings, envelope and bleached sulfite and sulfate paper cuttings, coated book stock, and computer printout. Print-free grades are reported as pulp substitutes. Printed grades, if de-inked, are reported as high-grade de-inking. **Source:** American Forest & Paper Association

"The ratio of out-of-balance [non-ECU] caustic to ECU caustic is changing radically," says Billy Tullos, Philadelphia-based Elf Atochem North America's chlor-alkali business manager. "The demand for chlorine in pulp and paper production is declining while caustic is maintaining its volume at near historical levels." Many producers suggest that demand for chlorine in other areas, such as polyvinyl chloride, will keep overall chlor-alkali markets in balance. This balance ultimately will depend on if or how soon legislation or environmental moves force phaseouts of chlorine in other areas such as chlorinated solvents and chlorofluorocarbons, as well as in pulp and paper.

Soda ash opportunity

Alternative sources of caustic, other than ECU caustic, are one solution to meet the projected long-term shortfall. Shamel points out that there may be better opportunity for soda ash (sodium carbonate) as a substitute alkali, not in the immediate future, but later this decade when ECU caustic prices become high. Soda ash demand in the paper industry currently has been flat because of low caustic prices, but could grow 6 to 7% per year over the next few years, from a current fairly low basis of about 200,000 tons per year.

Soda ash may be used directly as an alkali or used, as is trona ore, to produce caustic soda which is then referred to as "chemical caustic." "The [chlor-alkali] cycle is expected to reverse itself again and so chemical caustic may indeed make sense in another couple years," says Shamel. "Caustic soda [supply] will be relatively tight again and that's when you will see either more of this direct use of soda ash or the startup of chemical caustic plants." Most chlor-alkali producers expect to see prices tightening up in mid to late 1994.

Soda ash generally offers two major advantages, economics and quality, as a substitute alkali in pulp liquor makeup, explains James B. Coward, pulp industry manager in FMC's alkali chemicals division in Philadelphia. On site at a paper mill, soda ash can be added directly in the causticizing process to form, on reaction with calcium hydroxide, caustic soda for pulping. Soda ash also may have potential in the on-site production of precipitated calcium carbonate, which is used as a paper filler, as a coproduct with chemical caustic.

Several conversions have been driven solely by quality issues, specifically the lower chloride content of soda ash, which is some 40 times less than regular-grade (diaphragm) caustic soda, says Coward. Excessive chloride in the pulp liquor recovery cycle not only acts as a corrosive agent but can lead to equipment problems and increased maintenance demands as well. However, a major impediment to switching to soda ash is the need for excess causticization capacity, generally not available at older mills.

Most recycled paper and paperboard are used again for similar products

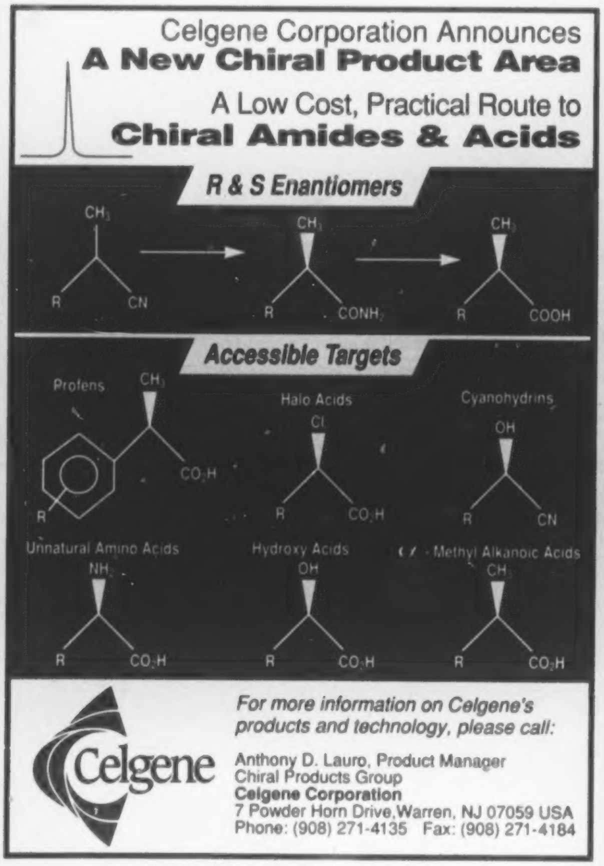
Recycle end use	Corrugated cardboard[a]	Newsprint	High-grade papers[b]	Mixed paper
Containerboard	55.5%	3.1%	4.0%	4.7%
Paperboard	22.6	20.7	9.8	41.9
Newsprint	0	32.6	0	5.9
Tissue	0.6	7.4	33.4	12.0
Printing/writing paper	0	0.7	28.7	1.8
Other	3.2	17.2	3.6	11.7
Exported	18.1	18.2	20.5	21.9
1992 TOTAL, millions of tons	**15.4**	**7.3**	**7.1**	**4.0**

a Includes kraft paper and bags. **b** Includes high-grade de-inking and pulp substitutes such as ledger, tabulating cards, bleached sulfate paper shavings, envelope and bleached sulfite and sulfate paper cuttings, coated book stock, and computer printout. Print-free grades are reported as pulp substitutes. Printed grades, if de-inked, are reported as high-grade de-inking. **Source:** American Forest & Paper Association

On an economic basis, average caustic soda prices exceeded $265 per ton FOB (free on board, or without fees for delivery to or loading on carrier) in 1990 through 1991 and may reach that level again by 1996. By comparison, soda ash—on an equivalent chemical basis—is about $130 per ton FOB at list price. Depending on the exact pulp mill location and application, says Coward, economics favor soda ash if caustic soda prices exceed $165 to $200 per ton delivered.

Chemical caustic is produced by three companies—FMC, Solvay, and Elf Atochem (in a joint venture with Texasgulf)—which each have a plant in Wyoming. However, these plants generally are running at only minimal rates, says Shamel. "Caustic prices are so low that once you make chemical caustic in Wyoming and ship it to market, producers can't compete with electrolytic caustic."

Tullos says Elf Atochem saw the trend toward non-ECU caustic several years ago and strategically decided to have a source of chemical caustic soda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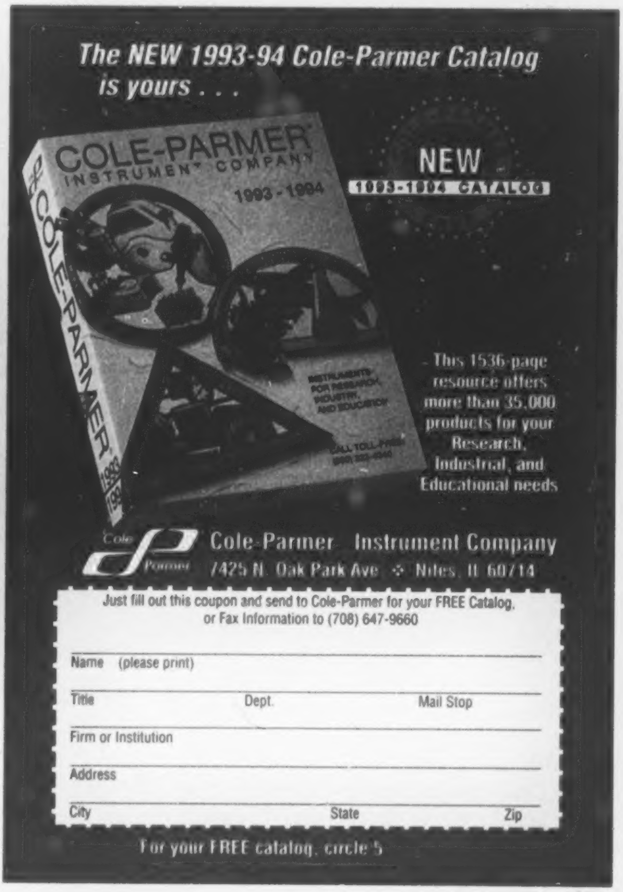
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available to the pulp and paper industry. "It allows the company to supply all the caustic soda that the pulp and paper industry customers might require regardless of whether there is a home for chlorine," he says, "and the company is not tied to the viability of a companion product which is being used less and less."

Chlorine use is dropping

Chlor-alkali producers have differing views on whether or when a phaseout of chlorine will occur in the pulp and paper industry. Some producers predict chlorine will be phased out by the end of the decade, whereas others suggest its use will decline and eventually level off. There even is disagreement on the rate of decline, ranging from a few percent to as high as 10% per year. Deciding factors will be the success of ardent environmental groups in their moves against chlorine, new regulations poised to come out, and consumer demands for chlorine-free paper.

Pulp and paper chemical markets to grow 6%

$ Millions	1990	1995	% annual growth
Papermaking chemicals	$1326	$1800	6.3%
Paper additives	900	1250	6.8
Pulping chemicals	729	915	4.6
Bleaching chemicals	657	875	5.9
TOTAL	**$3612**	**$4840**	**6.0%**

Source: Freedonia Group

Chlorine is by far the most widely used and largest volume pulp-bleaching chemical. For pulp to be used in most applications, such as the large markets for uncoated sheets of white paper or coated pages, it must be treated further to remove lignin and then generally is bleached. Overall, North American demand for pulp-bleaching chemicals—chlorine, sodium chlorate, hydrogen peroxide, and others—is expected to increase 2.6% per year to about 4 million tons in 1996, reports Freedonia Group.

Currently, about 1.2 million tons of chlorine, or about 9% of total production, are used annually in paper manufacturing. Chlorine's success has been based on the fact that it is inexpensive, extremely effective, and does not degrade the pulp. Its decline has been primarily because of environmental and regulatory limitations.

About 95% of mills use chlorine for bleaching, says Leslie Littell, chlorine product manager at PPG Industries, Pittsburgh, with usage declining 8 to 10% per year. In the U.S., on a relative basis, essentially no totally chlorine-free (TCF) paper is produced. Only a handful of mills produce small quantities of TCF paper as compared with a higher percentage in Europe. A larger number of U.S. mills are moving toward elemental chlorine-free (ECF) paper in which chlorine dioxide, rather than chlorine, is used as a bleaching agent.

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"What will affect the industry the most is the legislation to come out," says Littell. How strict the limits are on chlorinated organics and 2,3,7,8-TCDD will determine pulp and paper mills' abilities to meet regulations and afford the additional costs. "Some of PPG's customers say that as many as 12 to 15 mills could shut down because they are not making money now and they don't have the money to put in [new technology that may be] required to meet regulations," she says.

On the governmental front, attention has focused on executive orders being finalized by the Clinton Administration. At various times and to various degrees, these proposed orders have dictated government procurement of TCF paper, recycled fiber content, and "environmentally preferable" products. The U.S. government purchases between 1 and 2% of the more than 20 million tons of total U.S. printing and writing papers manufactured.

In late October, an executive order was issued directing federal agencies and the military to buy paper with at least 20% recycled content by the end of 1994, and 30% by 1999 (C&EN, Oct. 25, page 19). But, the Administration's stand on chlorine has eased, with the executive order only relaxing federal standards on paper brightness rather than requiring the purchase of TCF paper.

Other groups also are looking at procurement questions. This summer, the Paper Task Force was established to develop a market-based approach through which it can influence the way in which paper is produced, purchased, and used in the U.S. The seven organizations involved—Environmental Defense Fund (supported by the Heinz Family Foundation), Duke University, Johnson & Johnson, McDonald's, NationsBank Corp., Prudential Insurance, and Time Inc.—together purchase more than $1 billion of business printing and writing, publication, and packaging paper products.

Hoping to develop recommendations for increasing the use of "environmentally preferable paper and paperboard," the task force initially did not stress any preconceived definitions. Instead, its members are to assess their own needs and specifications for paper and paperboard with final purchasing decisions to be driven by a "comprehensive consideration of scientific and economic information on the environmental effects of paper production, use, recycling, and disposal." Analysis will include recycled and virgin papers, and papers produced by various pulping and bleaching technologies.

Task force members say they will work closely with their paper suppliers, as well as seek the views of experts in the pulp and paper industry, environmental and economic groups, and academia. In addition to changing its own members' use of certain paper products, the Paper Task Force hopes to design a purchasing model applicable to a broad range of organizations. A report is to be published in about a year.

Pressures on chlorine use

Both the Canadian and U.S. governments are issuing or pursuing regulations that focus on pulp and paper mill effluents. And, the International Joint Commission between the U.S. and Canadian governments, which advises the governments on issues concerning

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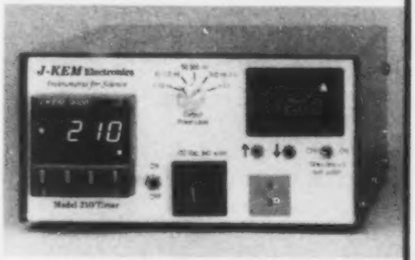

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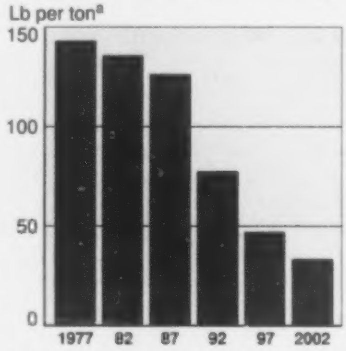
Chlorine use in U.S. pulp production is decreasing



[a] Estimated pounds of chlorine used per ton of bleached and semi-bleached kraft pulp
Source: Probe Economics

the Great Lakes region, has recommended eliminating chlorine in industrial processes. In the U.S., reauthorization of the Clean Water Act, Clean Air Act, and Resource Conservation & Recovery Act all are expected to have some impact on the pulp and paper industry.

A new bill, H.R. 2898, entitled the Chlorine Zero Discharge Act of 1993, has been introduced in Congress. This bill calls for an amendment to the Clean Water Act to completely eliminate discharges of chlorine compounds. It also specifically would ban the use of any chlorinated bleaching agent in the pulp and paper industry to prevent the formation of chlorinated organics. Chlorinated organics, the larger chemical family of which 2,3,7,8-TCDD is a member, have been targeted because of their persistence in the environment, tendency to bioaccumulate (accumulate in living organisms), and detrimental impacts on the environment and human health.

However, there is an ongoing debate over the full effect of chlorinated compounds (C&EN, April 19, page 11, and May 31, page 19). In addition to economic arguments that the chlorine industry has put forth against the phaseout of chlorine (C&EN, May 10, page 11), the Chlorine Chemical Council—a joint informational effort of the Chemical Manufacturers Association and several other trade associations—and the Chlorine Institute are still working to publish a massive report covering 150,000 different studies on the health and environmental effects of chlorinated organics.

Greenpeace, which is opposed to chlorine use in any industry, argues against using any chlorinated compound, not just elemental chlorine, in paper manufacture. The group asserts that there are an increasing number of ways to make high-grade paper without using chlorine that are not being practiced in the U.S. Mark Floegel, U.S. pulp-paper campaigner for Greenpeace, believes that the paper industry is trying to control demand for TCF paper by keeping such products off the market.

"The pulp and paper companies are not making any money and they don't want to spend money to recapitalize their mills until they absolutely [have to]," he says. "There also is a liability issue—to shift away from using chlorine is a tacit admission that chlorine is bad." He stresses that being chlorine free will not only reduce the presence of chlorinated organics in effluents, but also will allow pulp and paper plants to close process loops, recover chemicals, and reduce fresh water use. "I think it is inevitable that the industry is going to go chlorine free because the environmental benefits are too huge to ignore."

However, the Washington,-D.C.-based Chlorine Chemical Council says that TCF manufacturing is not a proven technology in bleached kraft pulp mills and that the environmental impact of TCF mills and paper is largely unknown. Chlorine producers and industry groups say that, with careful process controls, pulp and paper mills can use chlorine, often in combination with chlorine dioxide, and meet current regulations on 2,3,7,8-TCDD and chlorinated organics. Changes in paper manufacturing processes at modern mills have brought about reductions as high as 90% in the amount of 2,3,7,8-TCDD produced, says Brad Lienhart, managing director of the Chlorine Chemical Council.

Accordingly, the industry argues against the presumed benefits from TCF manufacturing and its relative costs—estimated to be as high as $13 billion in capital costs, $700 million in added operating costs, and nearly $2 billion in lost chemical business. Industry observers also question the ability to competitively produce high-brightness pulp with equivalent properties without chlorine bleaching. They also raise the possibility of adverse impacts on energy consumption and product recyclability.

In late September, 14 U.S. and Canadian chemical manufacturers and forest products companies formed the Alliance for Environmental Technology (AET). AET's mission is to "promote practical, proven advances in the environmental performance of modern papermaking, and to achieve sound Canadian and American federal, state, and provincial policies." The group hopes to address current policy debates in both countries that will influence the future of the North American pulp and paper industry.

Moves to chlorine dioxide

The Environmental Protection Agency will shortly announce its recommended rulemaking for pulp and paper effluent guidelines. The guidelines are the result of what has been called the "cluster rulemaking," a year-and-a-half-long investigation during which EPA simultaneously examined regulations covering different environmental media. The pulp and paper industry, which participated with EPA, industry, and environmental group representatives, was selected to be the first target of such rulemaking, according to Lienhart.

The proposed rules are to be followed by a two-year comment period. During that period, explains Lienhart, there also is a commitment to research—on how existing process changes are working

Use of pulp-bleaching chemicals in North America shifts away from chlorine

Thousands of tons	1985	1991	1996	% annual change 1991–96
Chemicals				
Chlorine	2,152	1,828	1,310	–6.4%
Sodium hydrosulfite	35	45	50	2.1
Sodium chlorate	680	1,157	1,830	9.6
Hydrogen peroxide	61	158	250	9.6
Oxygen and others	110	250	460	13.0
TOTAL CHEMICAL MARKET	**3,038**	**3,438**	**3,900**	**2.6%**
TOTAL PULP PRODUCTION	**36,214**	**40,565**	**44,700**	**2.0%**

Source: Freedonia Group

Union Camp photo

This pulper recycles an average of 500 tons of wastepaper per day

and on resulting effluent streams—as part of a continuing discussion on optimum process configurations. Once finalized, compliance with the rulemaking is expected to begin Oct. 31, 1995.

The rulemaking will offer what is generally viewed as a compromise for the pulp and paper industry. It is expected that limits to be set on air and water emissions can be met by using chlorine dioxide, instead of chlorine, in bleaching processes. According to Greenpeace, chlorine dioxide produces about one sixth the amount of chlorinated organics as does chlorine.

"The option of a heavy substitution of chlorine dioxide for chlorine would be a workable option that gets the industry to a point where it meets [standards], enhances recovery technologies, essentially eliminates the concerns about effluents, and still allows the industry to make top quality products that are recyclable, energy efficient, and competitive globally," says Lienhart. "However, this carries with it a not insignificant price tag of about $6 billion [in capital investments] and increases the operating costs to the pulp and paper industry by $300 million a year."

AET also supports chlorine dioxide use as a technology for eliminating toxic pollutants from papermaking. "Lost in the 'crusade against chlorine' is the recognition of the superior performance of chlorine dioxide," says Doug Pryke, executive director of AET. "This process alternative—whose chemistry is fundamentally different from chlorine gas—is without rival both in terms of environmental performance and product quality.

"What we know about chlorine dioxide is surpassed only by what we do not know about the TCF alternatives. Apart from chlorine dioxide, all the other alternatives are virtual unknowns from an environmental standpoint."

However, Greenpeace disagrees and does not expect to be pleased with the rulemaking, asserting that chlorine dioxide is an entirely unacceptable alternative. "Because less chlorine is being put in the front end, of course, you are getting fewer organochlorines out the back," says Floegel. "But, because these are persistent chemicals, they won't go away once they are produced and will continue to build up in the environment.

"Chlorine dioxide is not the answer. It is a bad investment. It is a false investment. It doesn't solve anything, it only delays the problems. The real investment is to be completely chlorine free." Floegel believes the expense of converting to chlorine dioxide technology will have significant ramifications in the future. "By forcing the paper industry into a chlorine dioxide mode," he says, "EPA is locking them in because . . . industry is not going to want to change [technologies] until the investment has been amortized.

"Then there are two possible outcomes: In a couple of years, either the industry is going to have to spend a lot more money to go completely chlorine free, which means they will be very angry and upset, or EPA will not force industry to get rid of the chlorine dioxide technology, and the environment and human health are going to be paying a toll for it 20 to 30 years down the road."

Growth for chlorate

Many mills have already invested in alternative bleaching technologies with some estimates for conversion to chlorine dioxide as high as 50 or 60% of bleaching operations. Chlorine dioxide is produced on site at paper mills from sodium chlorate. Thus, the continuing conversion to chlorine dioxide has been a boon for sodium chlorate producers, because more than 90% of sodium chlorate production goes to the pulp and paper industry.

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Moves away from chlorine are viewed favorably by producers of substitute chemicals, says Shamel of Consulting Resources, because all of the alternatives cost more than chlorine and in general offer higher profit margins. Chlorate markets have been growing at double-digit rates and likely will continue to grow at nearly the same rates over the next few years. However, adds Shamel, producers have built excess capacity because many of them believed that the conversions would occur more rapidly than they have.

Major sodium chlorate producers in the U.S. include Eka Nobel, Elf Atochem North America, Kerr-McGee, and Occidental Chemical. Kerr-McGee, Oklahoma City, doubled its annual capacity for sodium chlorate to 123,000 tons in the second half of 1991 and operated at 80% capacity in 1992. In 1992, the company's sales volume for sodium chlorate climbed more than 35% from 1991. In the short term, the company predicts an annual market growth of about 8%, leveling off to about 3% over the longer term.

By the mid-1990s, says Freedonia Group, higher capacity utilization is expected to cause a strengthening in sodium chlorate prices. Freedonia Group sees overall sodium chlorate markets growing, primarily from demand in pulp bleaching, at about 10% per year from 1.2 million tons in 1991 to about 1.8 million tons by 1996.

Growth may slow in the future as conversions from chlorine to chlorine dioxide near completion. In addition, many industry observers believe that as a chlorine derivative itself, sodium chlorate may only be a short-term replacement for chlorine since demand for TCF paper products may spark a second round of bleaching chemical replacement late in the decade.

Bleaching alternatives

Despite sluggish pulp markets, other pulp-bleaching agents also are gaining in use. As in chlorination, the oxidation of lignin-containing compounds by hydrogen peroxide, oxygen, or ozone, followed by solubilization and extraction, removes the materials that add color or cause fibers to darken. Much of the overall growth in pulp-bleaching chemicals is anticipated to come from those chemicals whose use is driven by environmental benefits.

But the market has not been willing to accept a decrease in pulp brightness or strength, says Don Magid, senior business manager at Solvay Interox, Houston. Only a limited number of pulp and paper operations have converted to newer technologies, often on a pilot or trial basis, he says, because full-scale, continuously operating conversions would involve additional costs. However, as new processes become better understood, more widely used, and incorporated into new plant designs, the costs likely can be reduced. Other economic factors to be considered, he adds, are environmental liabilities and benefits realized in the marketplace.

As the move away from chlorinated compounds continues, says Magid, the most probable solution will not be a single technology, but rather a combination of processes that will depend on a mill's specific needs. For example, combinations of hydrogen peroxide, ozone, and oxygen delignification can be used to produce TCF pulp, or chlorine dioxide and oxygen delignification for ECF pulp. Hydrogen peroxide producers also are developing specialty bleaching technologies based on peroxygen chemicals such as peracetic acid, peroxymonosulfuric (Caro's) acid, and formamidine sulfinic acid (FAS).

Among the different delignification and bleaching processes, oxygen and chlorine generally are the least expensive options, says Ron Scheff, manager of peroxygen products at Du Pont, Wilmington. Initially, hydrogen peroxide was marketed as a cost-saving replacement for chlorine dioxide, but comparative costs have become very mill dependent, owing to upgrading in mill design and in bleaching technologies.

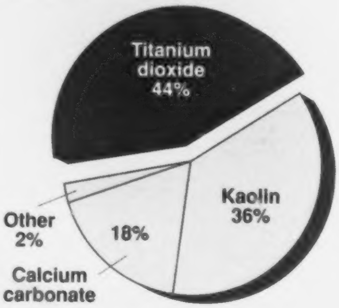
Because hydrogen peroxide decomposes into oxygen and water, it is considered among the most environmentally favorable pulp bleaches. Traditionally, it has been used to bleach mechanical and chemothermo-mechanical pulp and as a later-stage brightening agent for chemical pulp. Often, when having to convert from chlorine, says Scheff, paper mills commonly use their available chlorine dioxide capacity for early bleaching stages and, rather than invest in additional capacity, use hydrogen peroxide in later stages.

In addition to moves away from chlorine, increases in the use of hydrogen peroxide in other paper areas are helping to drive growth. Market demand is estimated by producers to continue growing at double-digit rates. Freedonia Group estimates the market will grow about 10% per year, from 158,000 tons in 1991 to 250,000 tons in 1996. Major hydrogen peroxide producers include Du Pont, Degussa, Eka Nobel, FMC, and Solvay Interox.

Although growth for hydrogen peroxide in the area of mechanical pulp has begun slowing, says Ken Blackburn, North American pulp and paper marketing manager for FMC's peroxygen chemicals division, its use is growing rapidly in the evolving recycled paper area. Also in the chemical pulp area, its use is projected to begin accelerating over the next few years in re-

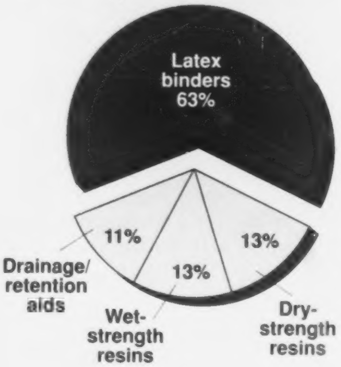
Researcher tests new paper coating at Air Products laboratory

TiO_2 leads mineral markets for paper . . .



1992 North American consumption = $1.2 billion

. . . and latex binders lead specialty paper chemicals



1992 North American consumption = $780 million

Source: Kline & Co.

sponse to environmental and brightness demands. But, adds Blackburn, facing the industry is the fact that hydrogen peroxide demand is quickly catching up with supply, leading to an anticipated supply-demand tightness in 1994.

Less than one fifth of the market for hydrogen peroxide used in making pulp and paper is consumed in processing secondary fibers. But this amount is expected to increase as more recycled paper facilities come on line in the next several years. Because the supply of recycled paper often is a combination of, for example, both newsprint and mixed office waste, chemical suppliers say hydrogen peroxide can be used to prevent alkaline darkening and increase brightness.

FMC has been helping the paper industry reach its targets in recycling different paper grades. In particular, because of competition for higher quality material to be recycled, the company has been helping manufacturers evaluate the trade-offs between switching to lower value materials and increasing chemical use to reduce costs.

Oxygen offers promise

Oxygen continues to be attractive for reducing the need for bleaching chemicals. Rather than act as a traditional bleaching agent, oxygen can delignify pulp and remove the color-containing elements. Other approaches to delignification include extended pulp cooking or the addition of enzymes. Oxygen delignification is becoming more common as an early pulping step, followed by chlorine dioxide, hydrogen peroxide, or ozone treatments.

The current total U.S. oxygen market in pulp and paper is about 1800 tons per day, says Stewart Mehlman, marketing manager for pulp and paper at Praxair, Danbury, Conn., and it is expected to rise to 2200 tons per day in five years. On-site paper mill generation of oxygen accounts for about 45% of oxygen consumed in papermaking and is expected to rise to 90% in five years. This trend can be attributed largely to the cost-effective combination of increased oxygen use at mills and to noncryogenic production methods that reduce production costs.

Oxygen delignification or ozone-bleaching processes may entail considerable capital costs, but oxygen suppliers say that operating costs can be less than those for other chemicals. "Realistically, it's a fairly inexpensive solution to reducing the amount of chlorinated organic discharges," says Dave Park, pulp and paper industry manager at Air Products & Chemicals, Allentown, Pa. "The company is working on a number of technical approaches to facilitate the reduction of chlorine compounds in both kraft pulp, through extended delignification with oxygen, and in secondary fiber."

Air Products has been working for several years on a group of processes that the company calls Oxypro O_R. "Recently, Air Products has accelerated its efforts to introduce oxygen-based processing into recycled fibers," says Park. The company has one commercial installation and a number of trials under way. "The use of oxygen in recycled fiber is ready to take off. Oxygen is a good base approach to be totally chlorine free in recycling paper."

The goal in recycled fiber is not to delignify, but to clean and brighten, Park explains, especially if dealing with office waste that is extensively delignified, white paper anyway. Oxypro is useful as a cleaning and brightening process for color stripping and for removing laser-printed ink and other kinds of dirt or contaminants, such as adhesives found in wastepaper. The process, he says, allows for economical processing and upgrading of mixed papers.

In general—not just for pulp and paper—oxygen capacity in the U.S. is "on the tight side," says Park, and demand for oxygen is growing in delignification processes and is expected to grow in the generation of ozone for bleaching pulp and paper. Praxair, Air Products, and other industrial gas producers such as Airco are looking to supply ozone technology for the pulp and paper industry. However, growth in ozone in the U.S. is pretty slow, says Park. Only one U.S. paper mill has an ozone system in operation today, and it still uses a final chlorine dioxide bleaching step. With little

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commercial and technical experience to date, ozone is not expected to make inroads until the second half of the decade.

Fillers add whiteness

Pigments or fillers can also add whiteness to paper. Recently, the use of pigments and fillers has picked up because of the trend toward lower weight coated papers, such as those used in magazines. This type of paper requires added materials for opacity and whiteness, and the desire for better quality graphics and four-color printing also increases the need for mineral-based surface coatings. During the next few years, the market for pigments and fillers is expected to grow several percent per year overall, but not all at the same rate for all mineral products.

The most commonly used pigment for opacity is titanium dioxide, with major producers including Du Pont and SCM Chemicals. The paper industry accounts for about 25% of the North American market for titanium dioxide, or about 250,000 tons, says Rob Johns, titanium dioxide market manager for paper at Du Pont. "The market grew about 2 to 3% in 1992 and about the same in 1993 ... and should continue to grow at that rate over the next four to five years."

Both titanium dioxide and kaolin producers experienced slow growth when the U.S. paper industry shifted to alkaline papermaking, which boosted markets for calcium carbonate at the expense of other fillers. Because calcium carbonate is stable at high pH, the shift allows this filler to be used. And, because alkaline processes produce a stronger sheet of paper, greater amounts of fiber could be replaced with less expensive fillers. At the same time, changes in precipitated calcium carbonate production that have recently reduced its cost—now about $130, or one half to one third the price of pulp it can replace—caused the market to flourish at double-digit growth rates, 10 to 15% annually, and helped further drive acid-to-alkaline conversions.

Du Pont worker inspects bleached pulp

"On an absolute basis, there was some reduction in titanium dioxide use as the industry went from acid to alkaline papermaking over the past six years," says Johns, "especially in the late 1980s when [the change] really got rolling. . . . But we believe that the alkaline conversions are pretty much complete and, thus, the impact on titanium dioxide, from this point going forward, should be minimal." Estimates for acid-to-alkaline conversions run as high as 80% of uncoated free-sheet (office, printing, computer, and writing) paper, and 90% of the coated free-sheet (catalogs, advertisements, annual reports) paper markets.

Johns argues, however, that titanium dioxide's value is greater than for other materials, since it offers the highest degree of opacity. Titanium dioxide is finding increased application in upgrading the quality of recycled paper, since weaker recycled fibers will limit the amount of other fillers.

The U.S. market for calcium carbonate in the paper industry, which is about 1.5 million tons per year, is dominated by Mineral Technologies, New York City, a spin-off of Pfizer, which began building the first satellite production units—located at or near major paper mills—for calcium carbonate in the mid-1980s. These plants produce a high grade of precipitated calcium carbonate using lime and carbon dioxide from a mill's own stacks. Mineral Technologies now has at least 34 plants across the world.

A recent trend has been the further modification of products to allow for increases in filler loadings, explains Walter Nazarowicz, Mineral Technologies' president for minerals. In the U.S., fillers currently are used at about 14 or 15% by weight, but this amount is expected to increase. In Europe, where pulp prices are higher and more stronger fibered softwood pulp is used, as much as 20 or 22% of a sheet of paper may be filler. Mineral Technologies is developing two other new forms of calcium carbonate. The first, called Ultrapaque, will compete with titanium dioxide as an opacifier; the second, unnamed, material can be stabilized under acid conditions.

Calcium carbonate also competes with kaolin in filler and coating uses. The largest kaolin producers for paper are Engelhard and English China Clays. Kaolin is available in a wide variety of grades and costs, depending on the particular application. Lower grade kaolin is used as a filler, whereas higher grade kaolin is used to provide the gloss of surface coatings. One of the advantages of kaolin is that it can be

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used in acid or alkaline papermaking conditions.

The kaolin market has been fairly static, says Ray Downey, director of marketing for paper pigments and fillers at Engelhard, Iselin, N.J., although there has been some growth in calcined kaolin coating grades, where the company focuses much of its business. "Growth for kaolin is down to about 2% per year, and that is the projection from now until the end of the century," he says, primarily because of competition from calcium carbonate and continuing acid-to-alkaline conversions. The U.S. market volume for kaolin is about 5 million to 7 million tons per year.

Positive trends for kaolin include paper recycling and an increased use of color printing in newspapers, says Downey. Historically, the newsprint market, based largely on groundwood pulp, used very few mineral fillers. "In the last few years, [newsprint producers] have been looking at adding minerals to improve brightness, printability, 'strike-through,' or other ink-related problems," he says. "But they usually are not set up to handle minerals very well and they want to add as little as possible while getting the most for their money. And that's meant growth in the calcined kaolin area for the last three years."

Need for binders is up

As the amount of minerals in alkaline paper increases, so too does the need for binders to hold fillers in place or in coatings. Increased recycled fiber content has required binder suppliers to develop technologies that accommodate the complications presented by recycled fibers. As more pigments are used to compensate for lower brightness fibers, the use of binders also will grow. Recycled fibers can add to the roughness of the paper and require binders and pigments in coating formulations for good smoothness.

Binders used in papermaking generally are latex, starch, protein, or specialty polymers. Polyvinyl acetate and other vinyl acetate resins are produced by manufacturers such as Air Products, Rohm & Haas, Union Carbide, Reichhold Chemicals, and National Starch & Chemical.

Product availability has been good for all emulsion products for coating binders, says Daniel Tafaro, marketing manager for paper at Air Products, and a slight upward trend in pricing is expected in the next year or two. To expand its polyvinyl alcohol-based products, Air Products is offering new products for optical brightening applications and for protein binder replacement.

The predominant binder chemistry for coatings is styrene-butadiene latex of which more than 500 million lb is used in the North American paper and paperboard industry, says Frank Cosmi, senior North American marketing manager of Dow Chemical, Midland, Mich.

About 150 million lb of other latexes and polyvinyl acetates are used as binders for coatings. Binder suppliers suggest that there have been moves away from polyvinyl acetate latex and toward styrene-butadiene latex in alkaline environments because polyvinyl acetate latex can cause problems with stickiness on machinery. Natural binders such as starch and protein account for another 750 million lb used in paper and paperboard coatings.

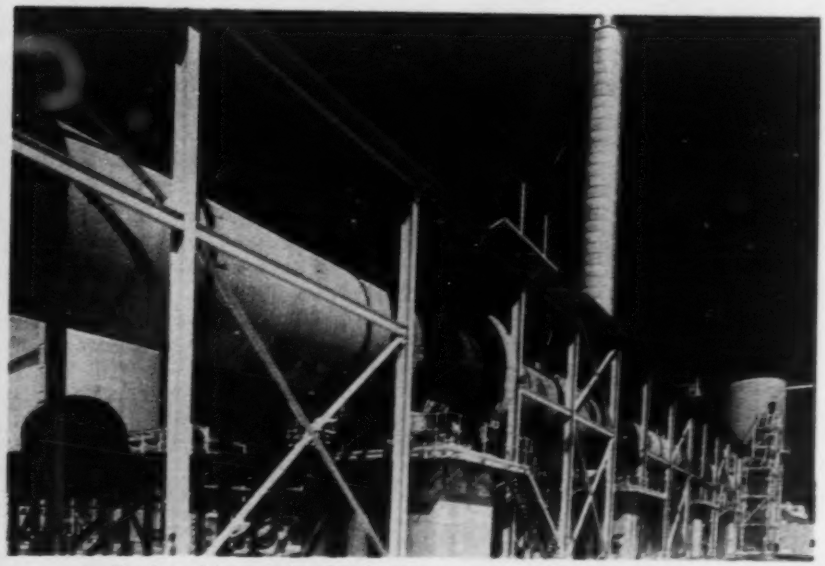
Binders generally are used in combination. Protein is used largely in paperboard, whereas starch and latex are used in higher grade papers. The higher the grade of paper, explains Cosmi, the greater the ratio of synthetic to natural binder. Latexes, which are much more expensive than natural binders, help provide smoothness, gloss, and good printed appearance to coated surfaces. Major latex producers include Dow, GenCorp, BASF, and Rohm & Haas.

Dow sells 80 different latex products for paper coating, based on a wide spectrum of technologies that have developed around the use of different pigments for different types of coated paper. Over the past decade, says Cosmi, growth in coated paper demand and a push toward higher quality papers contributed to a lot of substitution of latex binders for natural binders. The market for latex binders in coatings has had a fairly high growth rate, but now prices are tight. "The forecast is for that growth to taper off a bit," he says. "We are looking more at about 4% annual growth for the remainder of the 1990s.

"There is a public misperception that the paper industry is having to battle and that is that many people believe that coated paper is not necessarily recyclable," says Cosmi. This problem may stem from people being more accustomed to recycling uncoated newspapers and office waste or being aware of functional waterproofing coatings such as waxes or plastics that prevent paper or paperboard from being recycled. "Coated papers, where coatings are applied for printing purposes, are in fact readily recyclable and are recycled today. That's a concern that both the paper industry and the suppliers of binders share."

Alkaline sizing agents benefit

Along with fillers and binders, changes to alkaline papermaking have been a boon to the market for paper-sizing agents. Sizing, which adds the moisture resistance needed for printing, traditionally was based on alum-rosin chemistry in acid papermaking. Alkaline condi-



Kaolin calciner at Engelhard's Edgar plant in McIntyre, Ga.

tions have made it possible for reactive sizes, primarily alkylketene dimer (AKD) and alkyl succinic anhydride (ASA) sizes, to take over the market.

By the end of next year, says Robert Watts, business manager in Cytec's (West Paterson, N.J.) paper chemicals area, 95% of the uncoated free-sheet paper manufacturers in North America will be using alkaline processes. The reactive size market, estimated at about $60 million per year, is shared largely by Cytec, which produces ASA, and Hercules (Wilmington), which produces AKD and is the major producer of rosin-based sizes. Each of the two sizing products offers advantages and disadvantages in certain segments of the paper industry.

With ASA, Cytec focuses on the free-sheet market such as bond paper for forms and offset printing, where the paper is handled through high-speed printers, photocopy machines, or computer printers. Since ASA is very reactive, it typically is emulsified on site with starch (to stabilize and disperse it) and then put into papermaking equipment as an emulsion. The capital investment, about $100,000, is not significant, says Watts, compared with a mill's overall investment in papermaking equipment.

National Starch & Chemical, Bridgewater, N.J., supplies "wet-end" starches that are mixed with the pulp to add strength and retain reactive sizing agents. It also supplies surface starches that are applied after the sheet of paper has been formed to provide surface strength. The market for starches is expected to grow in applications in which starches can help strengthen inherently weaker paper because the paper is lighter weight or it contains more fillers, recycled fibers, or less expensive and weaker groundwood pulp.

A significant amount of starch goes into lightweight, groundwood coated paper, which must be able to withstand repeated runs through printing machines, explains Dennis Boyd, technical manager in National Starch & Chemical's industrial starch division. "Paper that is a better 'runner,' meaning that it runs longer between press cleanups, offers a competitive advantage." In 1989, to meet the need of the market, National Starch & Chemical commercialized a genetically modified corn-based starch called waxy-maize that contains only the high molecular weight, branched amylopectin component of starch.

Despite its need for emulsification, ASA 's faster curing time gives it an advantage over AKD, according to Cytec, and ASA also imparts less slipperiness to the paper—an important feature in cutting and printing applications. "To try to reduce the problems with AKD," says Watts, "some people are putting less internal sizing in the sheet and adding more surface sizes." Therefore, Cytec and other manufacturers are introducing new lines of surface sizes. "It depends on how you want to produce your paper, what is most cost effective, and what gives you the characteristics you want."

In contrast to ASA, however, AKD can be pumped directly into the paper-

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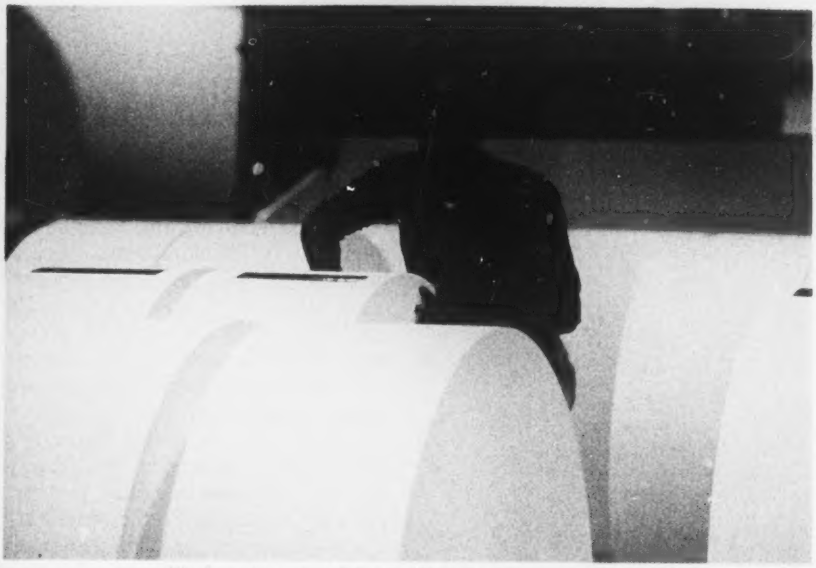

Weyerhaeuser photo

Worker at papermaking facility checks paper strength

making equipment in the same form as it is shipped and can be used in a broad range of applications, including paperboard and cartons. It's also a more powerful sizing agent which makes it applicable for paper-grade with higher filler loadings, says Thomas L. Giles, vice president, Americas, for Hercules' paper technology group. "AKD also runs better on the papermaking equipment, [causing] fewer deposits and [requiring] less cleanup."

Hercules gained its experience in alkaline size technology 20 years ago when Europe started converting from acid to alkaline papermaking, says Giles. Poised for growth today are neutral sizes that will compete with both acid and alkaline sizes. And the recycling of paper is providing challenges to size manufacturers with potentially heavier demands on chemical systems.

Processing aids needed

Heavier demands also may be placed on processing aids used in the production of paper. Processing chemicals include drainage and retention aids, dry-strength resins, wet-strength resins, defoamers, and biocides. Drainage and retention aids are principally specialty polymers, such as polyacrylamides. Dry-strength resins can be starch derivatives, whereas wet-strength resins include polyamides and urea formaldehyde. Hercules, Cytec, Nalco Chemical, Rohm & Haas, Rhône-Poulenc, PPG, and Betz PaperChem are among the suppliers of papermaking processing aids.

When a sheet of paper is formed, a slurry of pulp, fillers, and water is laid out on a screen or mesh. The water is then drained away and squeezed out as the sheets pass through large rollers. Drainage and retention aids allow the water to flow out while the fibers and other materials are retained in the sheet. Thus, the move toward higher filler loadings has increased the demand on retention aids and contributed to growth in that market.

"Today, about one third of the fine paper market uses some type of inorganic microparticle/polyacrylamide-based retention chemistry," says Eric Muchmore, business manager for performance chemicals in Cytec's paper chemicals department. Inorganic microparticles often have limited use because of high costs, variable performance, and handling difficulties. Cytec recently introduced a flexible micropolymer system that can be used with a range of pulps and fillers, he says, and that combines the cost and handling advantages of conventional polymers with the high retention, drainage, and formation benefits of inorganic microparticles.

Polymers are finding increased applications in de-inking processes and recycled papers. Weaker recycled fibers are contributing to growth in drainage and in dry- and wet-strength agents. And in recycling, once inks are separated from paper, polymers and surfactants remove the inks from process waters and effluents.

The removal of inks or toners from paper itself is an area of chemistry under a great deal of development. De-inking chemicals can affect fiber quality as well as the chemistry of later repulping, bleaching, and processing stages. FAS is being considered as a dye stripping and bleaching agent alternative to sodium hypochlorite, which is being phased out because it reduces pulp strength and produces chloroform in effluents.

Wet-strength agents also have been affected by environmental considerations. These materials allow paper products to retain their strength when wet, a useful feature in household products such as paper towels. Many wet-strength agents are based on polyamide epichlorohydrin chemistry, containing chlorinated organic by-products that may appear in paper mill effluents. Giles says that Hercules has introduced products that now have significantly reduced levels of the chlorinated organic by-products.

Bill Drury, assistant vice president for marketing services at Betz PaperChem, Jacksonville, Fla., says all polymer suppliers are having to meet demands for products that simultaneously allow for good drainage, retention, and formation of a sheet of paper. Polymers can provide more uniform formation in paper sheets, preventing breakage during the papermaking process, and improve the printability of the final product.

An individual polymer can enhance both drainage and retention at the same time, he explains, but unfortunately when drainage and retention are increased, formation can decrease. Specialty chemical companies are increasingly turning to multicomponent programs that try to achieve a balance between the three qualities required by paper mills.

Meeting the needs of paper manufacturers has become a continuing challenge not only for specialty, but for all, paper chemical suppliers. Although changes in the papermaking process have led to growth, chemical suppliers still must strike a balance between product performance, environmental considerations, and market demands. The future of the paper industry will depend largely on its improved profitability and the pressures and direction of legislation regarding solid waste, the phasing out of certain chemicals, and other environmental concerns. □

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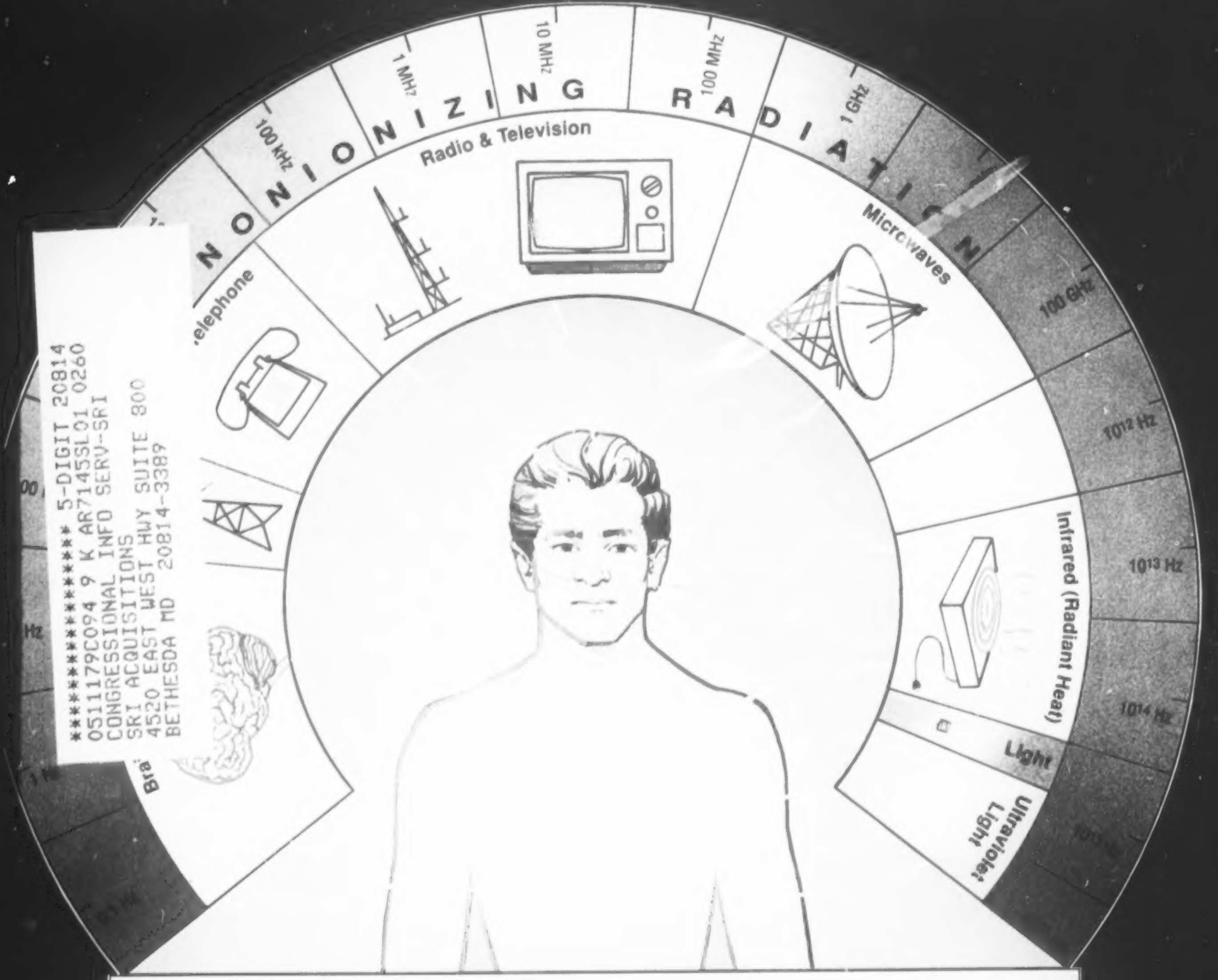
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Health effects remain unresolved despite extensive research Page 15

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NEWS OF THE WEEK

- EPA proposes rule to sharply cut air and water discharges of toxics from pulp and paper mills, requiring drastic curbing of chlorine use for bleaching. Page 5
- ACS and Dialog Information Services have settled out of court the lawsuits they filed against each other focusing on Chemical Abstracts Service; terms of the settlement weren't disclosed. Page 6
- Film for commercial printing that doesn't use silver halide or chemical developers has been invented by Xerox. Page 6
- Key protein that serves as an early trigger for autoimmune process that leads to diabetes has been identified by two independent groups of researchers working with mice. Page 7
- Pentagon is reviewing findings by a Czech chemical decontamination unit that it detected low levels of chemical warfare agents in the air during the Gulf War. Page 7
- Controversy swirls around charges that Formosa Plastics plant at Point Comfort, Tex., dumped wastewater before receiving clearance from EPA. Page 8

COVER: Illustration by Marvin J. Fryer

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Degussa Corp. has steadily built its reputation as a U.S. specialty chemicals producer and now begins to pay dividends to its German parent firm, Degussa A.G. **Page 32**

GOVERNMENT

Congressional activity has focused on White House proposals and preparatory work on the North American Free Trade Agreement for the past two months. **Page 36**

Rep. George Brown's bluster about earmarking of research money pays off, as millions of dollars for pork-barrel projects are pared from appropriation bills for fiscal 1994. **Page 38**

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Closest approach to the silylium ion, a triisopropyl silyl species weakly bound to a brominated carborane, is reported by University of Southern California chemists. **Page 41**

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ACS Arthur C. Cope Award and Cope Scholar Award winners: Roberts, Brookhart, Dowd, Foote, Jacobsen, Newcomb, Ojima, Roush, Schuster, Taylor, and Verdine. **Page 46**

NEWS FOCUS

Questions about health effects of exposure to electromagnetic fields remain unresolved, in part because research, although extensive, is complicated and also because results often have been contradictory. Page 15

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LETTERS

A world without chlorine

During the past week, numerous articles have appeared in the press either condemning or supporting the continued manufacture of chlorine and chlorine-containing materials. Greenpeace, the International Joint Commission, and the Michigan Medical Society are hoping to ban the manufacture and use of chlorine because it is hypothesized—but hardly proven—that extremely low levels of some chlorinated compounds may present a small risk to human health. Manufacturers, on the other hand, argue that chlorinated materials account for 40% of the U.S. economy and many thousands of jobs. In my opinion, as a retired chemist who spent 40 years in halogen research, I do not think that either side has framed the argument in terms that the public can understand or even relate to.

The question is not whether people can live without chlorine, as surely we can. After all, we got by quite well up to 1810 when chlorine was discovered, and can do so again. If the public chooses to revert to the life-style of the 1850s, it is free to do so. To do so would solve the health care problem, because medicine would also revert to that available in the 1850s. The cancer problem would be solved because the average life expectancy would decrease to about 45 years and few people would live long enough to get cancer.

I chose 1850 as the cut-off point for modern medicine because this is when chloroform came into its own as an anesthetic agent, permitting the use of lamps, electrical equipment, and x-rays in operating rooms without risk of incinerating the doctors, nurses, and patients, as often happened with ether. Between 1850 and the 1960s, millions of patients, doctors, and nurses inhaled many tons of the substance. Admittedly, there were deaths caused by chloroform. These were mostly caused by doctors overdosing the patient because they did not have modern metering systems.

Chloroform is now usually referred to as trihalomethane, a euphemism that hides the fact that the name chloroform is widely known to the public. I doubt that use of the proper name chloroform would stir up much fear since the compound was used for many years in over-the-counter cough medicines. It is unlikely that there are many people over 20 who haven't taken in considerable quantities of it. Chloroform, when called trihalomethane, is the same substance that the Environmental Protection Agency claims might cause cancer if consumed in drinking water in parts per billion. The amount that the average person can take in this way would appear to be trivial compared with the amount the average surgeon took in by inhaling the operating room air. Because of this fact, I would expect that if one examined the data, there should have been a large drop in the cancer rate of surgeons and operating room personnel during the past three decades. However, examining such data is not high on either the environmentalist's or EPA's list, since doing so and reporting the results might cause them to lose credibility. (Note the wide publicity given to the negative results of a 20-year study of the "victims" of the infamous "poisioning of Michigan" by polybromobiphenyl—a material reputedly as bad as dioxin. The *Detroit Free Press,* May 8, has the only reports of the results of this study that I have found.)

To those who may argue that because chloroform has been replaced by newer anesthetics, chlorine is no longer needed, I would like to point out that every inhalation general anesthetic agent in use today, except ether, is a product that relies on chlorine for its manufacture.

What I have said about medicine applies equally well to other industries that are obviously not critical to an 1850 life-style, such as telephones, electronics, automobiles, defense, computers, and so forth. It is difficult to think of any industry that did not already exist in 1850 that is not a product of people's ability to manipulate raw materials through the use of this most important element. Obviously, even Mother Nature has not found a way to do without chlorine, since algae pump billions of tons of it into the atmosphere every year.

In closing, I suggest that the Luddites and their financial backers are alive and well. Only the names have changed, but their objectives remain the same: Give me back the good old days, and down with progress.

Eric R. Larsen
Midland, Mich.

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Brown cuts millions in research earmarks

Rep. George E. Brown (D.-Calif.), who has been waging a lonely little war on the pork barreling of research money, is finally claiming some success for his decade-long efforts. By assigning his staff to pore through dense conference reports, convincing the House to change certain rules, personally arguing colleagues into seeing his side, and snorting fire on the House floor, Brown, chairman of the House Science, Space & Technology Committee, says he has apparently saved about $212 million that might otherwise have gone into pork-barrel projects in the fiscal 1994 budget.

The figure may seem piddling alongside the billions spent on defense programs or domestic entitlements, but Brown thinks the symbolism is significant. He believes that Congress' undemocratic system of playing fast and loose with public R&D money has been dealt a crippling blow. And in hearings in September he explored the unsavory process whereby lobbyists collude with and pressure politicians to fund projects favored by influential people in their districts. An organization especially targeted for Brown's criticisms was Cassidy & Associates of Washington, D.C., probably the foremost practitioner of the art.

Brown released the data in a press briefing on Oct. 27. The Defense Department's appropriation bill had not yet passed Congress, so its figures were not included. But Brown was hoping that the $260 million in earmarked projects added to DOD's $471 million Technology Reinvestment Program (TRP) would at least have to undergo peer review before any funds were handed out. TRP is a Clinton Administration initiative aimed at helping Defense Department contractors convert to technologies that dually serve the civilian and military markets.

Brown says he worked hardest to end earmarking practices in two separate appropriation bills: those from the Subcommittee on VA, HUD & Independent Agencies, and the Subcommittee on Energy & Water Development. Those bills provide money for agencies such as the Environmental Protection Agency, the Federal Aviation Administration, the National Aeronautics & Space Administration, the National Science Foundation, and the Department of Energy. Fiscal-year 1993 examples include $2.3 million for a food marketing center at St. Joseph's University, Philadelphia; $6.9 million for an air traffic control training center at the University of Alaska; and $10 million for a coastal resources center at Louisiana State University.

Top earmark recipients got over $1 billion since 1980

$ Millions	
Iowa State University	$91.6
University of Alaska	91.2
Oregon Health Sciences University	84.9
Louisiana State University	71.0
University of West Virginia	71.0
University of Hawaii	70.0
University of Rochester	65.3
Florida State University	58.7
University of Alabama	57.0
Boston University	56.5
Tufts University	46.0
University of North Dakota	43.4
Michigan State University	42.7
University of Illinois	39.2
University of South Carolina	36.8
University of Oregon	35.2
Indiana University	34.9
University of Florida	34.3
North Dakota State University	30.7
Loma Linda University (Calif.)	29.5

Note: Top 20 earmark recipients, 1980–92.
Source: "Trends in the Distribution of Apparent Academic Earmarks in the Federal Government's FY 1980–92 Appropriations Bills," Congressional Research Service, September 1992

The value of earmarks in the Energy & Water bill declined 78%, from $177 million in fiscal 1993 to $38.6 million in fiscal 1994. Earmarked funds in the VA, HUD bill dropped from $60.2 million to $7.7 million, or 87%, according to Brown's figures. These reductions mean that funding that had crept through the back door into appropriations reports were, in the end, not approved.

Earmarking in the Agriculture Department's appropriation bill, which Brown did not focus on but had figures for, dropped from $97.7 million to $70 million. But it did rise in the bill for the Departments of Commerce, Justice, and State—$76.5 million to $82.8 million. "The slight rise in earmarks in that bill," he says, "indicates that the subcommittees involved have not taken to heart our message." Still, he says, the record this year satisfied him. "Energy & Water and VA, HUD represented 58% of the earmarks among these four bills in fiscal 1993," he says. "They now account for just 23%."

In his briefing to reporters accompanying the release of his report, Brown said he used various techniques to reverse the increase in earmarking money, "including making an ass of myself" by his speeches of protest on the House floor. But mainly, the work involved convincing members of other authorizing committees to seek a rule change that allows chairmen of authorizing committees to force floor votes on items that are not mentioned in House or Senate appropriation bills.

Another technique involved using the Democratic caucus—the process by which Democrats formulate uniform positions on procedures and issues—to require appropriations committees to give 24 hours' advance notice to authorizing committees before bills are finally appropriated. That requirement serves to give time for the authorizing committee members to undo additions made by their earmarking colleagues.

According to a Brown staffer, the seminal political event favoring Brown occurred last year during consideration of the Energy appropriation bill. Brown had succeeded in knocking 10 projects totaling $100 million out of DOE's budget. His motion won by a large vote.

"But those same projects," says the staffer, "were snuck back into this huge Defense appropriation bill which no one normally took the time to read." After finding the insertions, Brown delivered an angry speech on the floor, terming the action an "affront to the institution." As the staffer puts it, Brown said, " 'Deal with me now or you'll have to deal with 100 new members of Congress next year.' It was a one-person campaign."

Brown, of course, would like to end pork barreling permanently. He thinks that his success in getting the House rules changed will go a long way toward achieving that. He believes that the appropriations committees have gone too far in attempting to change the content of agency programs. That is the job of authorizing committees, he says.

Brown laments that the Clinton Administration has not talked with him in opposing the practice. On Sept. 27, he wrote to Vice President Gore to request that the Clinton Administration issue an executive order requiring agencies to disregard earmarks that appeared only in conference reports. As of press time, Gore had not replied.

Wil Lepkowski

CHEMICAL & ENGINEERING NEWS

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NOVEMBER 15, 1993

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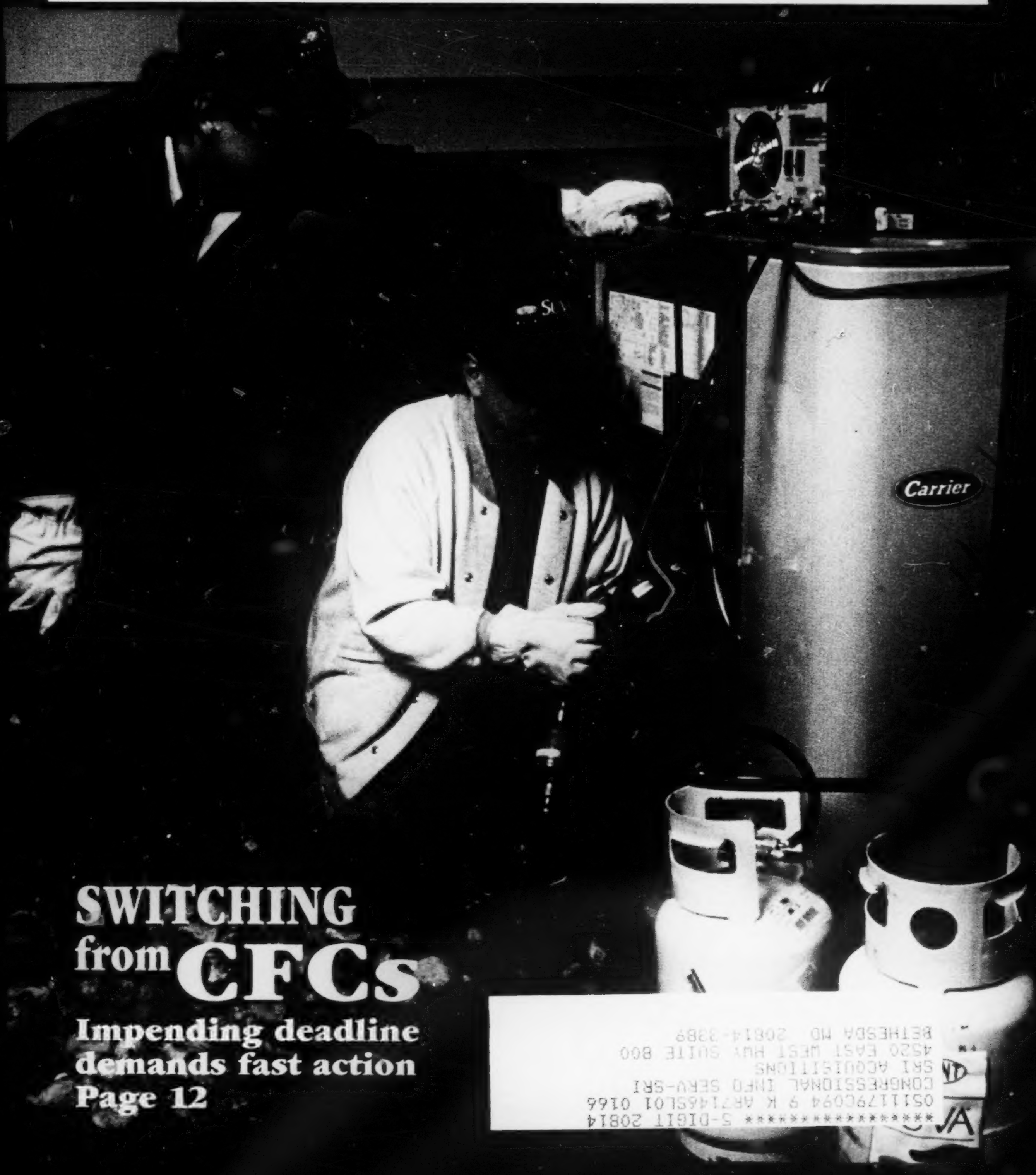

SWITCHING from CFCs

Impending deadline demands fast action
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CHEMICAL & ENGINEERING NEWS

C&EN

NOVEMBER 15, 1993

NEWS OF THE WEEK

- Scientific misconduct charges against AIDS researcher Robert Gallo will be dropped, sources say, after appeals board reverses charges against coworker Mikulas Popovic; but two other probes continue. **Page 8**
- FDA approves for marketing Monsanto's genetically engineered bovine somatotropin, which increases milk production in cows; opponents start vigorous campaign to prevent its use. **Page 9**
- Two research groups combine scanning tunneling microscopy with ultrafast laser optics to create tool for probing events on picosecond scale. **Page 9**
- Dutch chemical group Akzo will acquire troubled Swedish chemicals maker Nobel Industries for $1.7 billion. **Page 10**
- The original Bakelizer, used to make the first synthetic plastic, was designated as the first National Historic Chemical Landmark during a ceremony at the National Museum of American History. **Page 11**
- Huntsman continues its acquisitions aimed at diversification by agreeing to buy Monsanto's linear alkylbenzene and maleic anhydride businesses. **Page 11**

COVER: Photo courtesy of DuPont

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BUSINESS

Third-quarter earnings for major U.S. chemical companies were up for the second consecutive quarter, although not as much as earnings increases for oil and drug firms. **Page 22**

Slower growth is in store for the chemical industry over the next few years as a result of many structural changes taking place in the U.S. economy as well as in foreign economies. **Page 28**

GOVERNMENT

Occupational Safety & Health Administration idles while reform measures and confirmation of administrator languish in Congress; meanwhile, industry looks for action on several fronts. **Page 52**

SCIENCE/TECHNOLOGY

Development of first synthetic receptors may lead to a new form of human gene therapy from the ability to use small molecules to control gene transcription in living cells. **Page 55**

EDUCATION

The underrepresentation of ethnic and racial minorities in science and engineering is being addressed through efforts at all levels of education and in various arenas. **Page 59**

BOOKS

"The Greenhouse Gambit: Business and Investment Responses to Climate Change" offers an understandable, clever, and integrative look at global warming. **Page 63**

NEWS FOCUS

As ban on production of ozone-depleting chemicals nears, users move to adopt substitutes while industry works toward elimination of these compounds; however, environmental groups press for immediate, chlorine-free solutions. Page 12

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LETTERS

Dismissal of technicians

Although the 1994 Employment Outlook shows the unemployment situation for chemists is one of the poorest encountered in the past few decades (C&EN, Oct. 25, page 36), the job outlook for experienced technicians is a catastrophe. With new B.S. chemists commanding a median salary of only $24,000, career technicians—usually without a degree but earning much more because of long years of pertinent experience—have become a disposable commodity in the workplace.

ACS has been active in encouraging the career development of these technicians by sponsorship of papers by these individuals at local, regional, and national meetings. Now, with a crisis brought on by a substantial difference between the alarmingly low salaries of starting B.S. chemists and career technicians, our profession has the duty to protest the dismissal of competent technicians well versed in modern techniques of chemistry and, until now, indispensable in our research laboratories. To fail to be responsive to the current difficulties of this group would be a disgrace to our profession.

I appreciate the need of corporations to remain competitive; however, the dismissal of technicians on the basis that new B.S. chemists can be employed for less than what current technicians are being paid should not be tolerated. This matter should be of concern not only to the officers of ACS, but to all members of our profession.

Nelson Marans
Silver Spring, Md.

Book review rebuttal

In his review of my book "Element of Risk: The Politics of Radon" (C&EN, Oct. 11, page 35), M. Granger Morgan's criticisms as well as praise are largely matters of opinion. But he also cites two supposed errors of fact. The first is an oversight that refers to MeV as megavolts rather than million electron volts. The second "error," however is a puzzling misconstruction of my words.

Morgan quotes my passage that "risk [from radon] is higher if exposure is at an older age," as if this were my own proposition. He claims in any case that the proposition is wrong. In fact, I state unambiguously that the observation is that of Jonathan Samet and Richard Hornung ("Element of Risk," AAAS Press, Washington, D.C., page 28). In their review article concerning studies of miners [*Risk Anal.*, **10**, 70 (1990)], they note "an increasing risk with older age at initial exposure." Morgan's dismissal of the finding is offered without support and appears unwarranted.

Morgan's lapses are especially striking in view of his professed concern about detail and accuracy. At the end of his review he is identified as involved with "issues of risk analysis and risk communication for which the technical details are of central importance." Moreover, he writes that my (alleged) inaccuracies "jar the technical reader." Throughout his review, Morgan refers to my book as "Elements of Risk" [sic].

Leonard A. Cole
Faculty Associate
Program in Science, Technology & Society
Rutgers, the State University of New Jersey
New Brunswick

M. Granger Morgan, in his review of "Element of Risk: The Politics of Radon" (C&EN, Oct. 11, page 35), makes a brief reference to "rules of extrapolation and margins of error in other risk management decisions." This vital topic is often carefully avoided in the politics of environmental and other hazards. Readers may be referred to a commentary article in *Discover*, November 1993, by Robert Root-Bernstein entitled "Future Imperfect." In summary, he says, "Extrapolating from the past into the future is not a science but a highly fallible art."

Models on climate, global warming, ozone depletion, and epidemics, to name a few, are criticized as not sufficiently reliable for predictive extrapolations to be the basis of political actions. "Extrapolations, for the present, must remain a tool for analyzing the state of our scientific knowledge rather than a science for directing the tools of state," says Root-Bernstein.

Harold M. Kelley
Aiken, S.C.

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Chemical Company Earnings Increase For Second Straight Quarter

William J. Storck,
C&EN Northeast News Bureau

Chemical company earnings in this year's third quarter increased for the second quarter in a row. According to C&EN's quarterly survey of chemical results, earnings from continuing operations for 30 major chemical firms increased 5% from last year's third quarter, performing better than a group of diversified chemical producers, but trailing earnings growth at oil companies and pharmaceutical firms.

In the second quarter of 1993, earnings for the same group of chemical companies increased 8% from second-quarter 1992. Among these companies, Praxair, the industrial gases firm spun off from Union Carbide, has replaced Quantum Chemical, which has been acquired by Hanson plc, the U.K.-based diversified company. Prior quarterly data have been restated to reflect this change.

Also, American Cyanamid results have been "reconstructed" by including in its total figures the results of its chemical operations, which it has carried as discontinued operations until the formal spin-off of Cytec. Without this reconstruction, the inclusion of American Cyanamid would make the table less chemically pure, since Cytec is the bulk of Cyanamid's chemical operations. After Cytec's spin-off as a separate company in January, Cyanamid will be replaced in C&EN's survey because it will no longer meet the criterion—50% or more of its sales from chemicals—for inclusion on the chemical company table.

The modest earnings increase for the 30 chemical companies came in a rather lackluster chemical economy. Government data show that production of chemicals and allied products improved

Chemical industry leaders for the third quarter . . .

Sales

Rank 1993		$ Millions	Rank 1992
1	Dow Chemical	$2,988.0	1
2	Monsanto	1,849.0	2
3	American Cyanamid	1,150.9	4
4	W. R. Grace	1,136.1	5
5	Union Carbide	1,130.0	3
6	Air Products	855.5	6
7	Rohm and Haas	799.0	7
8	Arco Chemical	782.0	8
9	Hercules	676.0	9
10	Morton International	619.6	13

Earnings[a]

	$ Millions	Rank 1992
Dow Chemical	$139.0	1
Monsanto	95.0	9
Great Lakes Chemical	68.5	5
W. R. Grace	63.6	6
American Cyanamid	62.2	4
Air Products	59.6	3
Arco Chemical	55.0	2
Hercules	51.5	10
International Flavors	49.6	8
Morton International	42.9	11

Profitability

	Earnings as % of sales	Rank 1992
International Flavors	16.6%	1
Great Lakes Chemical	14.6	2
Nalco Chemical	10.9	5
Loctite	10.6	3
Betz Laboratories	10.0	4
Crompton & Knowles	8.6	9
Imcera	7.9	10
Hercules	7.6	13
Arco Chemical	7.0	6
Air Products	7.0	8

. . . and for the first nine months of 1993

Sales

Rank 1993		$ Millions	Rank 1992
1	Dow Chemical	$13,555.0	1
2	Monsanto	6,020.0	2
3	American Cyanamid	4,069.2	3
4	Union Carbide	3,567.0	4
5	W. R. Grace	3,216.4	5
6	Air Products	2,514.2	6
7	Rohm and Haas	2,509.0	8
8	Arco Chemical	2,325.0	7
9	Hercules	2,058.7	9
10	Morton International	1,848.1	13

Earnings[a]

	$ Millions	Rank 1992
Dow Chemical	$690.0	1
Monsanto	436.0	2
American Cyanamid	329.9	3
Air Products	205.7	4
Great Lakes Chemical	202.8	6
International Flavors	166.8	7
Arco Chemical	154.0	8
Hercules	150.1	10
Rohm and Haas	150.0	5
W. R. Grace	149.2	9

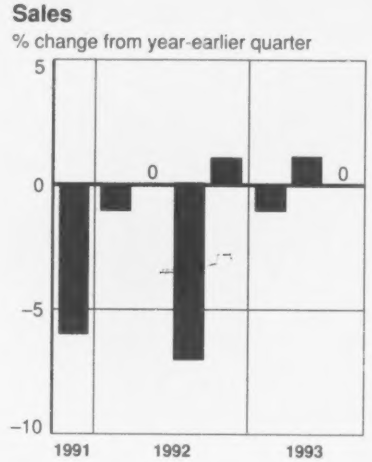
Profitability

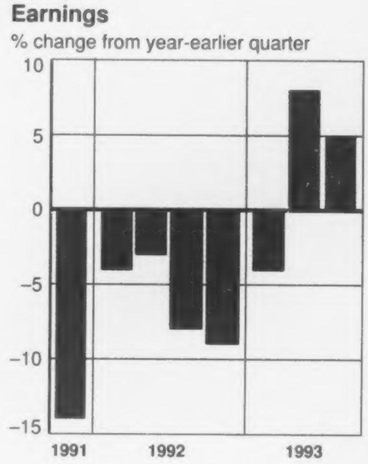
	Earnings as % of sales	Rank 1992
International Flavors	18.0%	1
Great Lakes Chemical	14.9	2
Loctite	11.6	3
Betz Laboratories	10.8	4
Nalco Chemical	10.8	5
Crompton & Knowles	9.5	12
Air Products	8.2	7
Lubrizol	8.2	6
American Cyanamid	8.1	8
Imcera	7.8	10

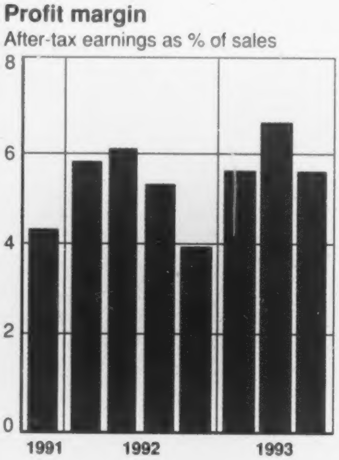
Note: Based on 30 chemical companies listed on page 24. [a] After taxes.

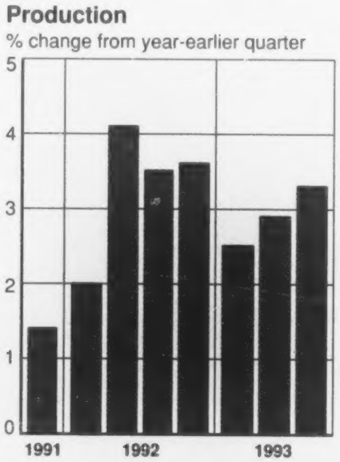
Chemical industry 1993 third-quarter results

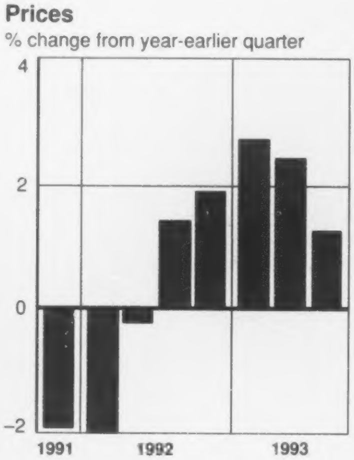
- **Sales were unchanged**
- **Earnings increased 5%**
- **Profit margin was 5.6%**
- **Production was up 3.3%**
- **Prices rose 1.3%**


Sales
% change from year-earlier quarter


Earnings
% change from year-earlier quarter


Profit margin
After-tax earnings as % of sales


Production
% change from year-earlier quarter


Prices
% change from year-earlier quarter

Note: All sales, earnings, and profit-margin data are based on 30 chemical companies listed on page 24.

about 3% during the quarter on a year-to-year basis, while prices rose only slightly more than 1%.

However, there was some good news in major chemical markets. Sales of automobiles improved, especially late in the quarter. And sales of new homes, also up late in the quarter, were well above analysts' expectations. If these two major markets for chemicals can continue to hold up, chemical industry sales and earnings likely will continue to grow.

However, countering any improvement in domestic business is the continued recession in foreign markets. Chemical companies point out that they are still being hurt by the poor economies in Europe, especially Germany, and in Japan.

The improvement in chemical company results was by no means across the board. Of the 30 companies surveyed, 11 still reported earnings declines from year-earlier results. And although earnings were up for the total group, sales did not show any growth from last year's quarter.

In the third quarter, sales for the 30 companies totaled $18.6 billion, virtually unchanged from the same period a year earlier. And the earnings increase brought total earnings from operations, excluding unusual items, to about $1.04 billion. The result was an increase in the aggregate profit margin—earnings as a percent of sales—for the group to 5.6%; in last year's third quarter this measure stood at 5.3%.

The increase in chemical company earnings was bested both by drug firms and by oil companies that produce chemicals. For the 10 pharmaceutical companies surveyed by C&EN, third-quarter earnings increased 29% to $3.28 billion on a 3% sales decline to $18.7 billion. The result was an increase in the aggregate profit margin for these companies to 17.5% from 13.1% in the comparable period last year.

For 11 oil companies, earnings in-

Third-quarter earnings increase 5% at major chemical companies to $1.04 billion

	THIRD-QUARTER 1993						NINE-MONTHS 1993			
	Sales	Earnings[a]	Change from 1992		Profit margin[b]		Sales	Earnings[a]	Change from 1992	
	($ millions)		Sales	Earnings	1993	1992	($ millions)		Sales	Earnings
Air Products	$ 855.5	$ 59.6	2%	–8%	7.0%	7.7%	$ 2,514.2	$ 205.7	2%	0%
American Cyanamid[c]	1,150.9	62.2	–4	2	5.4	5.1	4,069.2	329.9	0	2
Arco Chemical	782.0	55.0	–1	–26	7.0	9.4	2,325.0	154.0	0	–26
Betz Laboratories	176.5	17.6	–3	–18	10.0	11.7	516.5	55.6	–3	–10
Cabot	391.9	15.4	2	117	3.9	1.9	1,218.3	47.8	4	5
Crompton & Knowles	134.0	11.5	2	14	8.6	7.6	415.5	39.5	9	46
Dow Chemical	2,988.0	139.0	–7	–9	4.7	4.7	13,555.0	690.0	–5	32
Ethyl	486.9	29.8	6	34	6.1	4.8	1,451.7	87.0	19	32
First Mississippi	113.3	0.8	10	–54	0.7	1.7	341.3	2.6	–8	–50
H. B. Fuller	252.2	8.8	6	–15	3.5	4.3	727.5	20.6	4	–22
Georgia Gulf	199.6	11.4	0	5	5.7	5.5	576.7	32.7	–1	–13
BF Goodrich	500.8	17.2	–23	537	3.4	0.4	1,330.0	20.1	–30	63
W. R. Grace	1,136.1	63.6	8	13	5.6	5.3	3,216.4	149.2	9	16
Great Lakes Chemical	469.7	68.5	28	14	14.6	16.4	1,361.7	202.8	25	18
Hercules	676.0	51.5	–5	27	7.6	5.7	2,058.7	150.1	–5	24
IMC Fertilizer	266.4	–18.4	21	def	def	8.4	745.1	–35.0	–3	def
Imcera	444.9	35.3	7	28	7.9	6.6	1,383.2	108.2	5	5
International Flavors	298.7	49.6	2	1	16.6	16.9	929.1	166.8	7	8
Loctite	153.4	16.3	–4	–24	10.6	13.5	460.6	53.4	0	–19
Lubrizol	390.8	27.1	8	42	6.9	5.2	1,148.6	93.9	–4	–13
Monsanto	1,849.0	95.0	–2	107	5.1	2.4	6,020.0	436.0	2	–1
Morton International	619.6	42.9	15	23	6.9	6.5	1,848.1	131.8	16	19
Nalco Chemical	354.0	38.7	1	11	10.9	10.0	1,040.5	111.9	2	7
Olin	606.8	5.0	5	–15	0.8	1.0	1,824.2	31.0	0	–39
Petrolite	92.6	5.2	18	28	5.6	5.2	258.7	15.2	9	29
Praxair	608.0	36.0	–7	9	5.9	5.1	1,825.0	107.0	–7	11
Rohm and Haas	799.0	29.0	–1	–43	3.6	6.3	2,509.0	150.0	9	–18
Stepan	111.1	3.2	1	–17	2.9	3.5	336.3	11.2	2	–3
Union Carbide	1,130.0	38.0	–9	73	3.4	1.8	3,567.0	121.0	–3	21
Witco	540.6	22.9	27	21	4.2	4.4	1,643.2	62.7	29	12
TOTAL	**$18,578.3**	**$1,037.8**	**0%**	**5%**	**5.6%**	**5.3%**	**$61,216.4**	**$3,752.8**	**1%**	**4%**

a Earnings from continuing operations, excluding significant nonrecurring and extraordinary items. **b** After-tax income as a percentage of sales. **c** Includes discontinued operations. **def** = deficit.

creased 13% to $3.47 billion, despite a 19% decline in sales to $71.5 billion. For these companies, the profit margin increased to 4.8% from 3.5% in last year's third quarter.

For nine diversified companies with significant chemical operations, earnings were essentially unchanged from last year's third quarter, at $1.25 billion, on a 4% sales decline to $22.7 billion, providing a cumulative profit margin for the group of 5.5%, compared with 5.3% in the comparable three months of 1992.

The good news for the chemical companies is that the increase in the third quarter puts them, in total, solidly on the plus side for the first nine months of the year. In the January through September period, the 30 chemical companies posted total sales of $61.2 billion, up 1% from the same period in 1992. Earnings for the group increased 4% in the first three quarters to $3.75 billion. As a result, the chemical companies' profit margin increased to 6.1% in the first nine months of this year from 5.9% in the comparable period of 1992.

Despite the improvement in earnings, chemical company executives are still concerned about weak overseas economies and what to do about them. At Dow Chemical, executive vice president Enrique C. Falla, says, "Business conditions remain difficult, especially in Europe, and require even greater focus being placed on our quality and productivity initiatives. It is gratifying to report that the response of the organization to today's challenges has resulted in the reduction of research, promotion, selling, and administrative expenses and interest charges by more than $200 million compared with 1992. These productivity improvements will continue."

Air Products & Chemicals chairman H. A. Wagner points out: "Our operating performance reflected higher overall results in our industrial gas and chemical segments, despite a significant deterioration in European profits due to currency and weak business conditions."

Also concerned about the state of the European economies, W. R. Grace president and chief executive officer J. P. Bolduc says, "Although operating earnings were reasonably ahead of the year-ago period, we are concerned with the

NINE-MONTHS 1993		12-MONTH RUNNING DATA			
Profit margin[b]		Change from 1992		Profit margin[b]	
1993	1992	Sales	Earnings	1993	1992
8.2%	8.4%	3%	2%	8.3%	8.4%
8.1	8.0	–2	3	7.6	7.2
6.6	8.9	2	–16	6.4	7.8
10.8	11.6	–2	–6	11.0	11.5
3.9	3.9	4	–4	3.7	4.0
9.5	7.1	13	20	9.0	8.5
5.1	3.7	–2	–24	3.0	3.8
6.0	5.4	23	32	7.8	7.3
0.8	1.4	–7	–62	0.6	1.4
2.8	3.8	6	–12	3.2	3.9
5.7	6.4	1	–15	5.4	6.5
1.5	0.6	–14	def	0.6	def
4.6	4.4	–6	9	4.5	3.9
14.9	15.7	24	25	14.9	14.9
7.3	5.6	–4	25	6.9	5.3
def	5.9	–8	def	def	6.7
7.8	7.8	5	10	7.5	7.1
18.0	17.7	8	9	17.0	16.9
11.6	14.2	1	–8	12.0	13.2
8.2	9.1	–4	–18	7.4	8.6
7.2	7.5	–9	15	5.8	4.6
7.1	6.9	13	15	7.0	6.9
10.8	10.3	4	8	10.9	10.4
1.7	2.8	–2	–39	1.5	2.5
5.9	4.9	6	9	5.5	5.3
5.9	4.9	–5	8	5.5	4.8
6.0	7.9	10	–14	5.7	7.3
3.3	3.5	2	–7	3.3	3.6
3.4	2.7	–2	190	3.0	1.0
3.8	4.4	29	–2	3.5	4.5
6.1%	**5.9%**	**0%**	**1%**	**5.4%**	**5.4%**

impact of continued European weakness on most of our specialty chemicals businesses. We have no intention of simply waiting for improvement in the European economies to favorably impact our results. Rather, all of these businesses are focused on reducing costs in Europe, as well as in the more mature markets in North America. We are also continuing to aggressively pursue opportunities in newly developing markets."

The theme of cost cutting to counter weak economies is pervasive in the company statements. Thomas L. Gossage, chairman, president, and chief executive officer at Hercules, says, "The third-quarter results again demonstrate our commitment to profit margin improvement. In a difficult economic environment, gross profit margins were up again while indirect expense (selling, general, and administrative expense and research and development) continued to decline."

DuPont, which took a massive restructuring charge in the third quarter, believes it is bringing its operations into line. "Although much of the bottom-line impact continues to be masked by poor economic conditions in Europe and Japan, we have made significant progress in every area of transformation that we have undertaken during the past two years," says chairman Edgar S. Woolard Jr. "We have made extraordinary and difficult changes, including job reductions, a reorganization of our businesses, divestitures, and major fixed cost and spending reductions. We will continue to pursue our objectives aggressively and make our businesses healthy within the time frame we have set for ourselves."

In terms of product categories, both petrochemicals and fertilizers remain weak. The best measurement of petrochemicals is chemical earnings at oil companies. For a group of five oil companies that have significant chemical operations—Amoco, Chevron, Exxon, Mobil, and Occidental Petroleum—chemical earnings declined 6% to $221 million. However, although chemical earnings were down at three (Amoco, Exxon, and Mobil), they were up at the other two (Occidental and Chevron).

Chevron, whose chemical earnings improved to $15 million, excluding special charges, from a loss of $9 million in third quarter 1992, notes that despite that increase, the petrochemicals industry continues to be plagued by oversupply.

Although Chevron is typical of the oil companies in complaining about oversupply in petrochemicals, Mobil, where chemical earnings fell to $9 million from $24 million in last year's third quarter, is more specific in noting weakness worldwide in polyethylene and films due to oversupply and sluggish economies.

Occidental, whose chemical earnings increased to $43 million in the third quarter from $29 million in last year's third quarter, says that operating earnings improved as a direct result of lower manufacturing and administrative costs. However, the company notes, although 1993 volumes improved, margins for most products were lower because of competitive pricing.

Fertilizers also were trouble spots. For instance, among fertilizer producers, First Mississippi's already depressed earnings declined 54% to a barely profitable $800,000, and IMC Fertilizer suffered an $18 million loss in the quarter.

At IMC Fertilizer's annual meeting, Wendell F. Bueche, president and chief executive officer, was harsh in his assessment of the marketplace and especially prices, which he noted were at 20-year lows. "During the past several months, we have experienced a marketplace characterized by pricing at ri-

Ground rules for C&EN earnings analysis

C&EN's quarterly report on financial performance of the U.S. chemical industry contains data from the 30 largest U.S. basic chemical companies and from 20 oil and diversified companies, each with more than $200 million in annual chemical sales, plus 10 pharmaceutical companies.

To be included in the table of basic chemical producers, a company must have at least 50% of its sales in chemicals. That is why DuPont, for example, is included in the table of diversified manufacturers.

In referring to chemical sales, C&EN means those chemicals whose molecular composition has been changed in the course of manufacture. Hence, chemical sales include those of traditional categories of basic petrochemicals and inorganics, organic intermediates and inorganic compounds, polymers such as plastics and fibers, and agricultural chemicals and specialty derivatives.

Third-quarter earnings rise at oil and drug firms, but not at diversified firms

	THIRD-QUARTER 1993						NINE-MONTHS 1993					
	Sales	Earnings[a]	Change from 1992		Profit margin[b]		Sales	Earnings[a]	Change from 1992		Profit margin[b]	
	($ millions)		Sales	Earnings	1993	1992	($ millions)		Sales	Earnings	1993	1992
OIL AND GAS COMPANIES												
Amoco	$ 7,220.0	$ 446.0	0%	–2%	6.2%	6.3%	$ 21,388.0	$ 1,276.0	2%	38%	6.0%	44.0%
Ashland	2,653.2	48.5	–6	306	1.8	0.4	7,327.5	90.7	–1	438	1.2	0.2
Chevron	9,200.0	565.0	–11	38	6.1	4.0	28,200.0	1,633.0	–3	61	5.8	3.5
Exxon	17,920.0	1,360.0	–42	19	7.6	3.7	83,134.0	3,780.0	–4	11	4.5	4.0
Kerr-McGee	819.2	18.8	–4	–35	2.3	3.4	2,448.5	76.9	–3	4	3.1	2.9
Mobil	15,819.0	613.0	–3	40	3.9	2.7	47,016.0	1,622.0	1	79	3.4	1.9
Occidental Petroleum	1,916.0	–46.0	–10	def	def	4.6	6,096.0	112.0	–1	0	1.8	1.8
Phillips Petroleum	3,170.0	56.0	2	–5	1.8	1.9	9,429.0	250.0	7	108	2.7	1.4
Sun Co.	2,384.0	61.0	–20	259	2.6	0.6	7,127.0	138.0	139	def	1.9	def
Texaco	8,479.0	255.0	–13	–25	3.0	3.5	25,441.0	848.0	–6	19	3.3	2.6
Unocal	1,963.0	91.0	–22	40	4.6	2.6	6,379.0	277.0	–16	94	4.3	1.9
TOTAL	**$71,543.4**	**$3,468.3**	**–19%**	**13%**	**4.8%**	**3.5%**	**$243,986.0**	**$10,103.6**	**–1%**	**36%**	**4.1%**	**3.0%**
DIVERSIFIED MANUFACTURERS												
AlliedSignal	$ 2,822.0	$ 168.0	–4%	24%	6.0%	4.6%	$ 8,778.0	$ 487.0	–2%	23%	5.5%	4.4%
DuPont	9,231.0	355.0	–5	–6	3.8	3.9	27,847.0	1,364.0	–3	25	4.9	3.8
Eastman Kodak	4,077.0	260.0	–4	–1	6.4	6.2	11,884.0	658.0	–2	7	5.5	5.1
Ferro Corp.	263.7	15.0	0	1	5.7	5.6	800.4	41.7	–1	–2	5.2	5.3
FMC	926.5	45.7	–5	–15	4.9	5.5	2,807.5	192.3	–6	–14	6.8	7.5
3M	3,481.0	316.0	–2	–2	9.1	9.1	10,538.0	977.0	0	3	9.3	9.0
NL Industries	202.1	–18.7	–13	def	def	def	622.0	–48.4	–10	def	def	def
PPG Industries	1,405.4	76.1	–2	15	5.4	4.6	4,375.7	241.1	–1	–4	5.5	5.7
Vulcan Materials	331.5	36.6	6	2	11.0	11.4	851.5	67.7	5	–4	7.9	8.7
TOTAL	**$22,740.2**	**$1,253.7**	**–4%**	**0%**	**5.5%**	**5.3%**	**$ 68,504.1**	**$ 3,980.4**	**–2%**	**10%**	**5.8%**	**5.2%**
PHARMACEUTICAL COMPANIES												
Abbott Laboratories	$ 2,060.4	$ 316.2	5%	13%	15.3%	14.2%	$ 6,179.8	$ 1,007.8	7%	13%	16.3%	15.5%
American Home Products	2,168.1	397.6	3	4	18.3	18.1	6,188.5	1,086.6	5	38	17.6	13.4
Baxter International	2,228.0	135.0	5	–9	6.1	7.0	6,484.0	324.0	5	–16	5.0	6.3
Bristol-Myers Squibb	2,862.0	608.0	–28	6	21.2	14.5	8,419.8	1,703.3	1	8	20.2	19.0
Eli Lilly	1,530.6	294.4	4	def	19.2	def	4,651.6	1,014.7	3	96	21.8	11.4
Merck	2,544.1	705.7	3	11	27.7	25.8	7,497.4	1,492.0	6	–19	19.9	26.0
Pfizer	1,872.5	310.8	2	4	16.6	16.3	5,488.5	893.5	4	10	16.3	15.5
Schering-Plough	1,061.9	199.4	4	14	18.8	17.1	3,274.9	636.1	7	15	19.4	18.0
Upjohn	899.9	153.0	1	5	17.0	16.3	2,747.4	431.0	4	6	15.7	15.4
Warner Lambert	1,478.5	155.9	3	–5	10.5	11.4	4,259.9	526.9	3	4	12.4	12.3
TOTAL	**$18,706.0**	**$3,276.0**	**–3%**	**29%**	**17.5%**	**13.1%**	**$ 55,191.9**	**$ 9,115.9**	**5%**	**10%**	**16.5%**	**15.7%**

a After-tax earnings from continuing operations, excluding significant extraordinary and nonrecurring items. b After-tax earnings as a percentage of sales. **def** = deficit.

diculous levels, oftentimes below direct cost. This is a formula for self-destruction of a business and, indeed, of an industry," he said.

In announcing the company's quarterly results, Bueche continued the theme in looking ahead at his company's fiscal year, which will end June 30, 1994. He notes some modest improvements in the quarter, including higher prices in some areas—although prices were still below year-earlier levels; increased fertilizer purchases by China; and anticipated increased domestic demand. "Nevertheless," he cautions, "despite these promising developments, IMC Fertilizer will not be profitable for fiscal 1994 unless there is significant price improvement."

In spite of the problems in petrochemicals and fertilizers and, indeed, of the entire chemical industry trying to cope with sluggish worldwide demand, chemical executives are sure that the cost-cutting measures that they have been making will pay off. This attitude is summed up by Praxair's chairman and chief executive officer, H. William Lichtenberger: "Looking ahead, actions being taken to better serve customers, improve operations, and reduce corporate overhead, together with higher operating rates and stabilizing pricing trends in the U.S., are providing the foundation for future earnings growth." ☐

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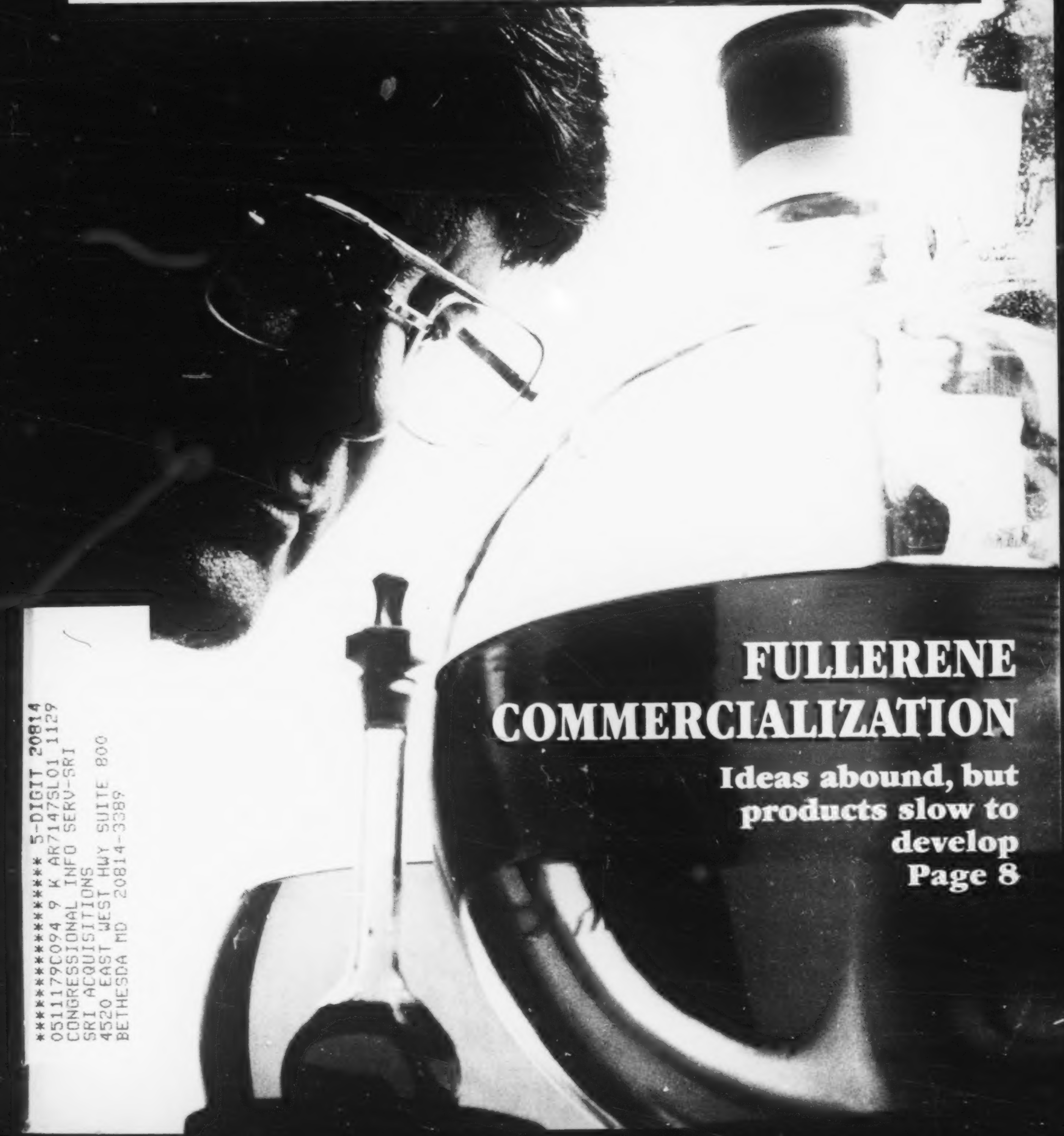
CHEMICAL & ENGINEERING NEWS

C&EN

NOVEMBER 22, 1993

ACADEMIC CHEMISTS BEGIN TO DEFINE RESEARCH ETHICS STANDARDS PAGE 24



FULLERENE COMMERCIALIZATION

Ideas abound, but products slow to develop
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CHEMICAL & ENGINEERING NEWS

C&EN

NOVEMBER 22, 1993

NEWS OF THE WEEK

- Chemical industry hails NAFTA passage by House of Representatives, expects strong growth in chemical exports to Mexico. **Page 4**
- Chemists at MIT synthesize a biodegradable copolymer that potentially could serve as a tissue matrix in the human body. **Page 5**
- Senate report berates EPA's failure to reduce toxic air emissions and smog; new EPA official pledges to do better. **Page 5**
- Winner of ACS presidential election is Brian M. Rushton, defeating Hank Whalen by more than 4,000 votes. **Page 6**
- Baxter International, maker and marketer of health care products, announces massive, costly reorganization that may eliminate 4,500 jobs. **Page 7**

COVER: Ronald Ziolo, senior scientist at Xerox Webster Research Center, Webster, N.Y., examines a flask containing a solution of C_{60}; the flask with amber-colored liquid contains a solution of C_{70}.

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Politics have played a role in prosecution of environmental criminal cases, with the U.S. Attorney General's office usurping local authority, witnesses charge at a House hearing. **Page 26**

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Operation of an international space station staffed by scientists from the U.S., Russia, and other countries may be a reality in 2001, if the White House approves submitted plans. **Page 29**

Guidelines for evaluating in-situ bioremediation projects are proposed by a National Research Council committee. **Page 30**

Breakneck pace of NFS's first materials chemistry workshop invigorates some attendees, disappoints others. **Page 33**

Novel crystalline carbon networks that can collapse in two directions are postulated by scientists' calculations. **Page 35**

BOOKS

"Murder, Magic, and Medicine" explores links between folk medicine and modern drugs in a delightful foray into one special aspect of the heritage of chemistry. **Page 36**

NEWS FOCUS

Although the unique physical and chemical properties of fullerenes and their derivatives continue to fuel speculation on possible uses, commercial markets for these compounds have been slow to develop. Page 8

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1155—16th St., N.W., Washington, D.C. 20036
Editor: Michael Heylin (202) 872-4501
Managing Editor: Madeleine Jacobs
Assistant Managing Editors: James H. Krieger, Janice R. Long, Rebecca L. Rawls, Donald J. Soisson, William J. Storck
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LETTERS

Mistaken identity

We wish to correct the reference to Knute Rockne described in John Meisenheimer's letter (C&EN, Oct. 25, page 2). Indeed, Rockne was a chemist as well as a football coach and he was well acquainted with Father Nieuwland, who developed vinylacetylene and chloroprene, the forerunners of neoprene. However, the archival picture in C&EN and referenced by Meisenheimer as demonstrating that Rockne was a chemist is not a picture of Rockne.

As we pointed out in a letter to the editor more than 10 years ago when the picture first appeared in C&EN (Sept. 28, 1981, page 44), the person in the archival picture and purported to be Knute Rockne in J. A. Nieuwland's laboratory at Notre Dame is in fact J. P. Young, our father, who graduated from Notre Dame in 1908. Various details in the picture, particularly the style of Nieuwland's biretta and the view of the terrain as seen through the windows, indicate that the photograph was taken around 1906, prior to Rockne's time at Notre Dame.

This has been confirmed by the Notre Dame archives office.

Jack P. Young
Oak Ridge, Tenn.
Jay A. Young
Silver Spring, Md.

NIST director Arati Prabhakar

I commend President Bill Clinton for choosing and Congress for confirming Arati Prabhakar as director of the National Institute of Standards & Technology (NIST) (C&EN, Sept. 6, page 19). Craig Fields was absolutely correct in recommending Prabhakar to replace John W. Lyons. The time is right to show the world that women and minorities are qualified to shape the U.S. and the world in the 21st century. Prabhakar has both imagination and flexibility, perhaps the most important attributes of a successful engineer, scientist, or policy shaper. We need people like her today.

One of the areas in which she can help the U.S. is by bridging the trade gap with Japan. Biomedical/biochemical engineering is the high technology of the future. Advances in this field will help to reduce health care costs, a major aim of the Clinton Administration.

To meet the challenge for global competitiveness, the U.S. must educate more people in high-technology disciplines. Space-age technologies must be brought into the mainstream. Because there is no longer any threat to the U.S. from the former Soviet Union, research on lasers, for example, can focus on biomedical applications.

NIST should not only look at the use of the latest materials in sporting goods, but also at their application in medical science. Technology, biotechnology, and biomedical engineering should be used to create national wealth—including brain power, the first and foremost national asset. The many unemployed engineers from defense-related industries are the superpowers of the earlier technological muscle power of the U.S. They could help to create the national wealth. I believe Prabhakar can play a key role in achieving this.

There is undue concern from NIST's staff regarding the appointment of a woman director and about the changes that will take place within NIST. Human beings never like change; however, change is a must in this day and age. When the late Indira Gandhi was appointed prime minister of India, similar concerns were voiced by politicians outside her party who doubted her ability to handle the premiership.

Harcharan Singh Ranu
Greenvale, N.Y.

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U.S. Ethylene Producers Ending 1993 With Higher Profitability

■ ***But major chemical faces tough time next year as higher feedstock costs, potential oversupply may cut into bottom line***

Susan J. Ainsworth, C&EN Houston

On a global scale, 1993 has been a poor year for producers of ethylene. However, during the past year, domestic ethylene makers have made considerable progress toward solving some of the problems that have plagued them during the past couple of years of industry downturn.

The best news, perhaps, is that U.S. ethylene producers have enjoyed higher profit margins compared with 1992, thanks mostly to lower raw materials costs this year. In addition, ethylene demand is gaining momentum. Ethylene, one of the largest volume commodity chemicals produced worldwide, is used as a raw material to make plastics, fibers, and other organic chemicals that are ultimately consumed in the packaging, transportation, and construction industries, and in many other industrial and consumer markets.

Ethylene's demand is extremely sensitive to economic cycles. For example, as the U.S. economy has strengthened, so has domestic demand for polyethylene, the largest market for ethylene.

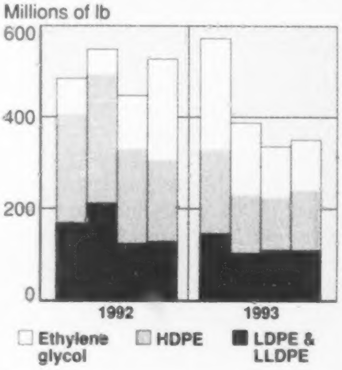
Another bright spot: Over the past year, producers have been more careful in synchronizing ethylene capacity additions with demand growth. As a result, U.S. ethylene producers are benefiting from higher plant operating rates, which are now averaging about 90% of capacity.

However, these improvements don't yet signal the beginning of an upturn. Between early 1994 and early 1995, four producers are poised to complete expansions that will bring a total of 4.0 billion lb of ethylene capacity onto the market. That wave of additional annual capacity likely will bring operating rates back to 85% or so of capacity, which "is no better than where rates were at the bottoming out point [of the current downturn] in the spring of 1992," observes William L. Urquhart, a senior consultant with Houston-based Pace Consultants. "So in 1994, ethylene producers probably will find themselves bouncing along the bottom of [the trough] again."

With the potential for greater oversupply on the horizon, ethylene producers' chief concern now is "how demand for ethylene derivatives will shake out in the coming year," says Urquhart. With several new plants for polyethylene and ethylene glycol coming on stream worldwide in 1994, ethylene producers are hoping that consumption will remain high enough to keep those plants running at respectable rates, thereby buoying demand for ethylene.

Ethylene demand, as always, will dip in December as producers of ethylene derivatives draw on stocks of their products at year's end, says Urquhart. "But early signals indicate that demand for derivatives looks pretty good into the early months of the new year." A market manager for one ethylene producer says, "We believe U.S. ethylene consumption will grow 2 to 3% in the near term, which, historically speaking, is not weak demand." Demand in 1993 grew at only about 1.7% over 1992, according to Urquhart.

Indeed, domestic demand for polyethylene has been on the rise for the past few months. For the year through August, domestic sales and captive use (excluding imports and exports) of linear low-density polyethylene (LLDPE) was up 5.7% over the same period in 1992 to reach 3.51 billion lb, based on the latest monthly statistical figures from the Society of the Plastics Industry. During that same period, domestic sales and captive use of high-density polyethylene (HDPE) rose 4.9% to 6.28 billion lb. However, domestic sales and captive use of low-density polyethylene (LDPE) dropped 2.7% in the January through August period of 1993 from the same period in 1992 to total 4.13 billion lb. "In this country," says Urquhart, "we are really fortunate that demand is holding up."



Net exports of key ethylene derivatives slip

Note: Net exports represent exports minus imports. Quarterly data; third-quarter and fourth-quarter 1993 are estimates. **Source**: Pace Consultants

The export picture, however, has not been as pretty. "Fifteen months ago, we witnessed a tremendous falloff in exports of derivatives, which coincides with poor economic conditions in many traditional export countries and the startup of competitive polymer plants in the Far East," says Urquhart. For example, according to Pace's forecast based partly on preliminary government data, it appears that net exports (exports minus imports) of ethylene glycol dropped about 9% to 105 million lb in the third quarter of 1993 compared with the same quarter last year. Similarly, over the same period, net exports of HDPE probably fell about 40% to 120 million lb and combined net exports of LDPE and LLDPE likely dropped about 13% to 110 million lb.

On the supply side, Formosa Plastics, a wholly owned subsidiary of Formosa Plastics Group, Taiwan, is slated to be the first of four producers to complete significant capacity additions between 1994 and early 1995. Formosa's plant is part of a $1.3 billion expansion at Point Comfort, Tex., that will add capacity for LLDPE, HDPE, ethylene glycol, polypropylene, and chlor-alkalies, as well as olefins. The company is currently in the shakedown stage of construction of the ethylene unit, which will have a capacity of 1.5 billion lb per year. Formosa has not yet determined when the plant will be ready for startup. Some observers speculate that the plant will begin production sometime during the first quarter of the new year, while others say a startup is imminent.

Formosa confirms that it will hold off startup of its olefins unit until its derivatives units are up and running smoothly on purchased ethylene. One holdup in that plan is the rebuilding of an incinerator that caught fire late last month in the new HDPE unit while the company was completing preoperational testing.

In another move, in the second half of 1994 Amoco Chemical will expand its capacity at Chocolate Bayou, Tex., by 550 million lb per year. In addition, Exxon Chemical plans to increase the ethylene capacity of its Baytown, Tex., olefins plant by 450 million lb per year late next year. This will raise the capacity of this facility, already the world's largest single train ethylene plant, to 2.5 billion lb per year. "This expansion is planned to meet the expected growth in ethylene demand from both our external customers and internal requirements," says Sherman J. Glass Jr., vice president of the Basic Chemicals Americas unit of Exxon Chemical. Earlier this year, Exxon expanded its ethylene cracker at Baton Rouge by 175 million lb per year.

Meanwhile, Dow Chemical is expected to finally start up a 1.5 billion-lb-per-year ethylene plant at Freeport, Tex., during first-quarter 1995. However, Dow may idle some of its existing capacity when the new plant is up and running; the company has facilities with about 700 million lb of capacity along the Gulf Coast that are nearly 30 years old. The decision as to whether it will shut down all or just some of that old capacity will be based on market conditions and demand requirements in early 1995, Dow says.

Although producers have been more careful in timing large increases in capacity to coincide with demand growth, production still continues to climb and is projected to break a record for 1993. For the year through the third quarter, production was up 2.7% over the comparable period in 1992, totaling 31.4 billion lb, according to figures released earlier this month from the National Petroleum Refiners Association (NPRA). Pace estimates that full-year production will reach 42 billion lb, up 1.3% from 1992.

NPRA inventory figures for the third quarter show more notable change over the same period last year. The past quarter's ethylene inventories are up 50% from third-quarter inventories in 1992. "Though inventories are up sharply versus a year ago, they are ample, not excessive," says Urquhart. "At 1.84 billion lb, stocks represent 16 days' demand inventory—ample and comfortable, and tending to the long side of the range of recent years, but only barely."

With supply and inventories being more than adequate for meeting market demand, it's not surprising that producers have failed in repeated attempts to raise the price of ethylene in 1993. When prices for ethylene raw materials rose in April, producers responded by announcing a 1 cent-per-lb ethylene price increase, effective May 1. That attempt failed as competition intensified in ethylene derivatives, and was postponed until June and then until July, when it faltered again.

Although ethylene producers were not able to boost the price of ethylene, their attempts did help to halt a slide in price earlier in the year, says Urquhart, noting that the "official" ethylene price has remained at 21 cents per lb since March. However, beginning in the third quarter, discounts of official prices (which are traditionally given to large volume and other special purchasers) have increased. Two weeks ago, discounting widened even more, lowering the average "transactional" price to below 17.5 cents per lb.

However, even with falling transactional prices, sellers actually have improved their profit margins for ethylene this year, Urquhart observes. Based on ethane feedstock purchased at contract price, Pace estimates that margins for ethylene producers are about 7.6 cents per lb this month, 1 cent higher than a year ago even though the transactional price is 2.5 cents per lb lower than it was then.

Improved profit margins can be attributed to the price of ethane—the major feedstock for ethylene production—which has fallen dramatically over the past several months. Earlier this year, prices for natural gas liquids (NGLs), including ethane, were high, so natural gas processors adjusted their plants to produce more of them. In the course of doing so, processors created an oversupply of NGLs, especially ethane. Inventories have built, peaking in September at 26 million barrels, and prices have dropped about 30% between April and this month, says Michael Horvath Jr., senior consultant, who tracks NGL markets at Houston-based consulting firm Bonner & Moore Associates Inc.

However, natural gas processors began to reject ethane in September, leaving more of this light gas in the natural gas stream. So, beginning this month, NGL prices have begun to firm and are expected to continue to rise into next year, Horvath projects. "But prices are not expected to rise so sharply so as to discourage consumption of ethane, which is expected to exceed 600,000 bbl per day through February of 1994," he adds.

With higher NGL prices on the horizon, ethylene profit margins are not likely to be as strong in 1994 as they've been in 1993. In addition, competition among downstream products is expected to intensify in the coming year, placing downward pressure on profitability, adds Urquhart.

Although ethylene producers do face a number of setbacks in the coming year, some are encouraged by the strides they've made in 1993. They are hoping, too, that a true turnaround is not far off. As one producer points out, except for the Dow startup early in 1995, no other U.S. expansions are planned for 1995 and beyond. ☐

Four producers plan to add ethylene capacity by early 1995

Company/ /location	Annual capacity (millions of lb)	Estimated startup date
Formosa Plastics Point Comfort, Tex.	1,500	Early 1994
Amoco Chemical Chocolate Bayou, Tex.	550	Late 1994
Exxon Chemical Baytown, Tex.	450	Late 1994
Dow Chemical Freeport, Tex.	1,500	Early 1995
TOTAL	**4,000**	

Source: Company data

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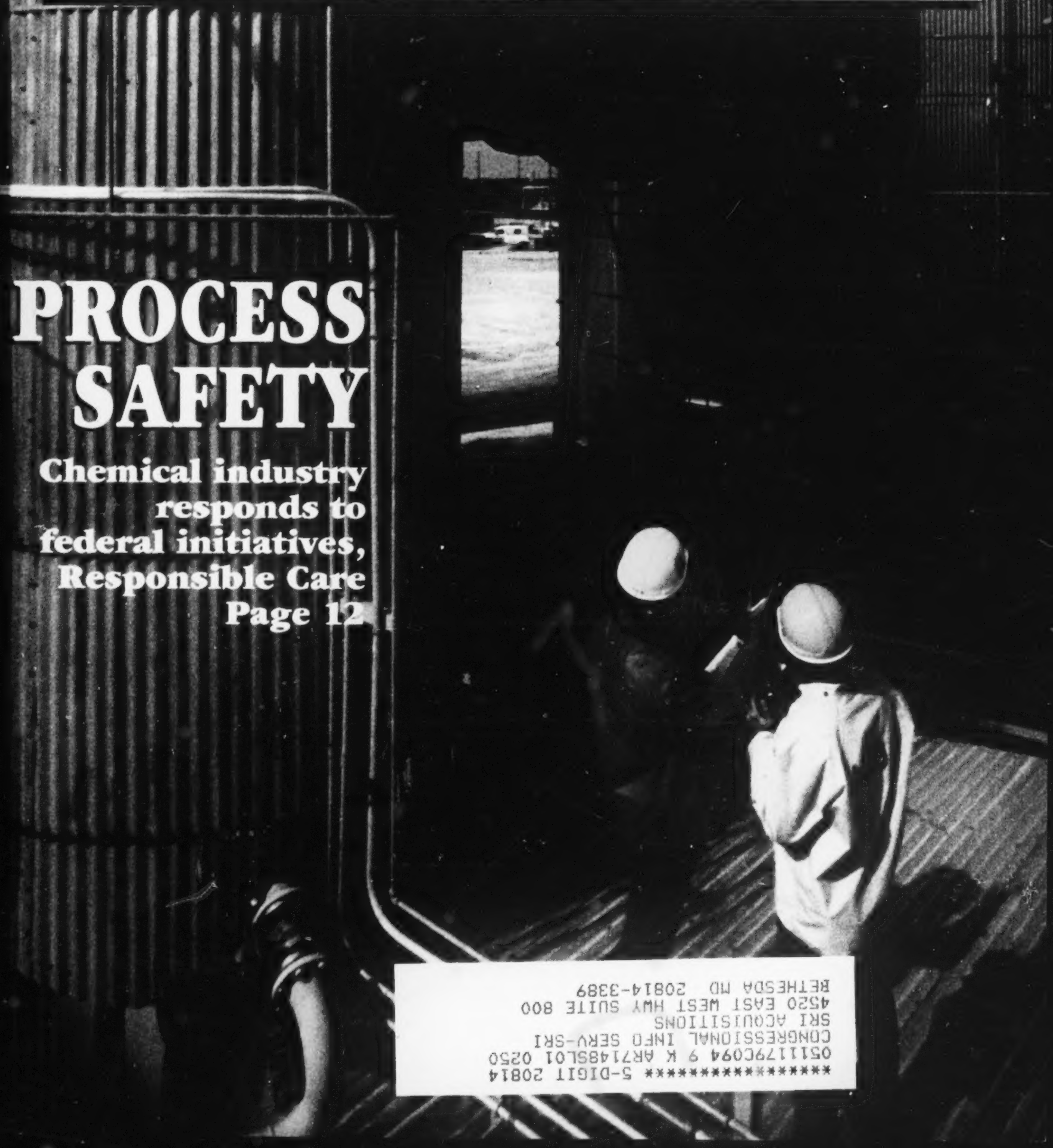
CHEMICAL & ENGINEERING NEWS

C&EN

NOVEMBER 29, 1993

MAJOR CHALLENGES FACE NEAL LANE AS NEW DIRECTOR OF NSF PAGE 45



PROCESS SAFETY

Chemical industry responds to federal initiatives, Responsible Care

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C&EN

NOVEMBER 29, 1993

NEWS OF THE WEEK

- Near-field scanning optical microscopy has been used by Bell Labs researchers for the first time to detect fluorescence emission from single molecules and to determine their distribution and spatial orientations on a surface. **Page 6**
- Clinton Administration unveils a new strategy that features a number of initiatives to promote export of U.S.-produced environmental technologies. **Page 7**
- EPA and the National Weather Service plan program to monitor trends in surface UV radiation and to inform the public in daily forecasts of potential health risks from exposure to UV. **Page 7**
- Scientists at Scripps have synthesized nanotubes consisting of stacks of cyclic polypeptides, allowing construction of nanotubes with a specific internal diameter and tailored surface properties. **Page 8**

COVER: Workers conduct plant safety check. Photo courtesy of DuPont

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BUSINESS

New $200 million specialty chemicals company, Freedom Chemicals, is assembled by partners Harold Sorgenti and Fred Rullo, through purchases of specialty intermediates and textile chemicals operations. **Page 42**

Demand for enzymes in the U.S. is likely to increase almost 10% per year between 1992 and 1997 because of environmental and regulatory pressures, says a new report. **Page 43**

GOVERNMENT

NSF's new director, Neal Lane, faces challenges in foundation's identity crisis and low morale and in balancing Congress' demands for more emphasis on strategic research with Administration's protection of basic science. **Page 45**

SCIENCE/TECHNOLOGY

Subtle tensions at the chemistry-biology interface—as organic chemists delve into the chemistry of biological systems—emerge at a conference on the frontiers of chemistry and medicine. **Page 50**

Two new oxides—dibromine trioxide and tetranitrogen monoxide—of common elements have been prepared independently by two research groups in Germany. **Page 51**

Stacked aromatic heterocycles in the interior of DNA appear to efficiently promote electron-transfer reactions over distances of more than 40 Å, suggesting that the DNA double helix acts as a "molecular wire." **Page 52**

NEWS FOCUS

The chemical industry is under increasing pressure to step up its safety efforts, prodded by new federal initiatives and proposed rules to track safety and manage risk. Page 12

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LETTERS

Apology

We would like to apologize to anyone offended by the advertisement we ran in the Nov. 1 issue of C&EN. The "he" in the phrase "Give a Chemist what he wants for Christmas ... Chem-X Can!" was meant in the general sense to refer to both "he" and "she." The advertisement was also booked for the Dec. 6 issue, and since there is not enough time to change it, we would like to apologize in advance.

Deborah Anne Dunn
Executive Vice President
Chemical Design Inc.
Mahwah, N.J./Chipping Norton, U.K.

Noise pollution solution

Your article about the cooperation of the Dutch government and the chemical industry (C&EN, Nov. 1, page 11) interested me very much because I worked in the Netherlands for four years.

We had many contacts with the Milieudienst, the Dutch Environmental Protection Agency, which was also very concerned about noise pollution. We had experienced some severe water hammer during the startup of new facilities, and a homeowner living about 200 yards away complained about the noise. We were told not to engage in such a noisy startup between 10 PM and 6 AM. Failure to comply would not incur a fine, but would mean the cancellation of our operating permit. Needless to say, we had to find a solution to the problem to avoid the restriction, and we did, by modifying the piping and the operating procedure.

Rudolph Pick
Pompano Beach, Fla.

Space station turkey

"The demise of the SSC [Superconducting Super Collider] undoubtedly will mean the demise of other good science projects" (C&EN, Oct. 25, page 6). But that demise does not necessarily amount to a purely "sad day for science."

The space station will cost at least $2 billion per year, not counting hundreds of million of dollars for further cost overruns. No worthwhile or unique scientific missions have been identified for the space station. This turkey qualifies for immediate action under National Aeronautics & Space Administration head Daniel S. Goldin's specifications that "We have mechanisms that will terminate programs that cross certain cost growth or performance thresholds."

Robert J. Good
Professor Emeritus
State University of New York, Buffalo

Differing views on EMF

During an uproar a few months ago in my neighborhood about the dangers of high-voltage power lines, I reviewed the literature. To my surprise and dismay, I found mainly a series of epidemiological fishing expeditions and bizarre theories and speculation.

I was saddened that C&EN would dignify the subject of electromagnetic fields with such a prominent place in the magazine (Nov. 8, page 15). Members of ACS deserve better than an uncritical recitation of a hodgepodge of junk science.

Gabor B. Levy
Wilton, Conn.

It is time I expressed my appreciation to Bette Hileman for her superb articles over the years in which she has collected and ordered the scientific work on diverse subjects, each of interest to me.

I think of ones ranging from "The Great Lakes Cleanup Effort," a Special Report (C&EN, Feb. 8, 1988, page 22) to the recent "Health Effects of Electromagnetic Fields Remain Unresolved," a News Focus. Her articles alone would make *Chemical & Engineering News* worth reading.

Majorie W. Evans
Los Altos Hills, Calif.

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New Initiatives Take Aim at Safety Performance of Chemical Industry

Progress continues toward implementing Responsible Care code and OSHA rule; new programs are proposed to track safety, communicate risks

Deborah L. Illman, C&EN Washington

Chemical makers have always been safety conscious. By the nature of the trade, they've had to be. Over the years, the chemical industry has prided itself on its safety record.

But today the industry is under sharply increased pressure to redouble its efforts to protect both its workers and its neighbors. At the same time, further improvements in chemical process safety are proving to be laborious, costly, and difficult for the public to track.

Propelling this greater emphasis on safety are two federal initiatives. One concerns the impact of chemical releases beyond the plant fence line, the other the release of hazardous substances within the workplace. In addition, a system to track plant safety performance under the Responsible Care program of the Chemical Manufacturers Association (CMA) is being finalized and may be in place as early as next year.

The Environmental Protection Agency's proposed risk management rule, published last month in the *Federal Register*, addresses risks beyond the fence line. It is designed to prevent, detect, and respond to the release of extremely hazardous substances from chemical processes. The proposed rule would require an estimated 140,000 facilities nationwide that use listed chemicals in amounts above certain thresholds to assess and publicly disclose the potential impacts of accidental releases, including the worst case scenario. Companies would be required to document a five-year history of releases and to develop and implement prevention and emergency response programs.

The proposed EPA rule is similar to and builds upon the process safety management (PSM) standard of the Occupa-

Responsible Care Process Safety Code

In September 1990, the Process Safety Code became the third in a series of Responsible Care codes of management practices to be adopted by the Chemical Manufacturers Association. The code is designed to provide guidelnes for preventing fires, explosions, and accidental chemical releases. It identifies areas where companies can improve their safety performance, from process design through operation and routine maintenance:

MANAGEMENT LEADERSHIP

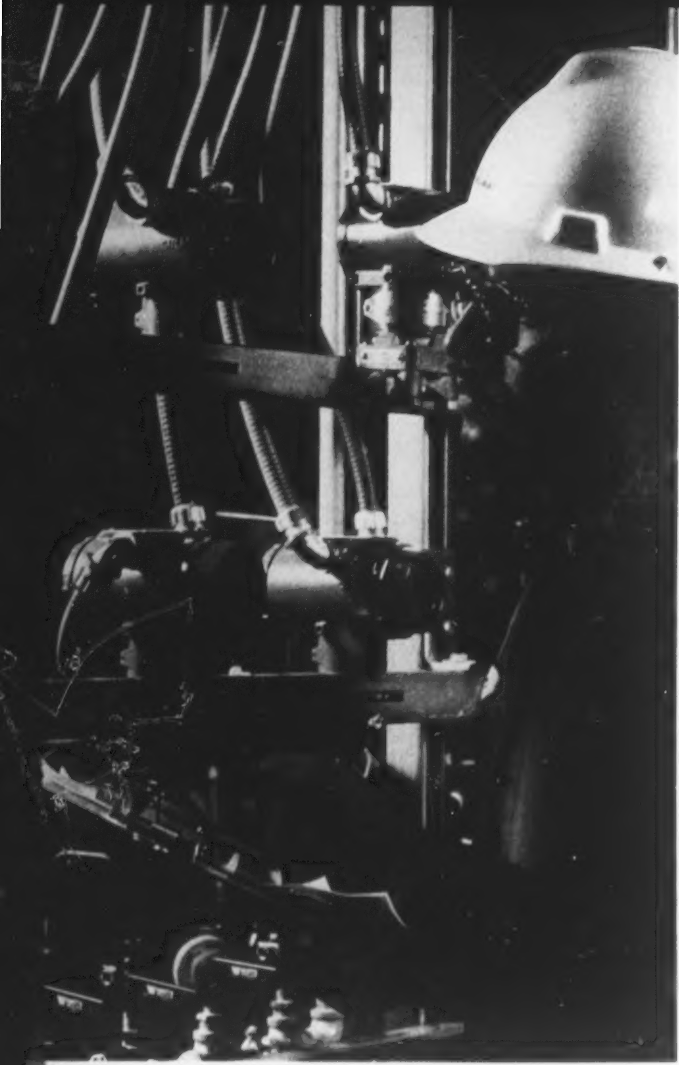
1. **Leadership in achieving continuous improvement in performance, through policy, participation, communications, and resource commitments.**
2. **Clear accountability for performance against specific goals for continuous improvement.**
3. **Measurement of performance, compliance audits, and follow-through on corrective actions.**
4. **Investigation, reporting, corrective action, and follow-up of each incident that results or could have resulted in a fire, explosion, or accidental chemical release.**
5. **Sharing of relevant safety knowledge and lessons learned with industry, government, and community.**
6. **Use of CAER (Community Awareness & Emergency Response) process to ensure public concerns are considered in design and implementation of process safety systems.**

TECHNOLOGY

7. **Current, complete documentation of process design and operating parameters/procedures.**
8. **Current, complete documentation of hazards of materials and process technology.**
9. **Periodic assessment and documentation of process hazards, and implementation of actions to minimize risks associated with chemical operations, including possibility of human error.**
10. **Management of changes to chemical operations to maintain or enhance the safety originally designed into the facility.**

FACILITIES

11. **Consideration and mitigation of potential safety effects of expansions, modifications, and new sites relating to the community, the environment, and employees.**
12. **Facility design, construction, and maintenance using sound engineering practices.**
13. **Safety reviews on all new and modified facilities during design and prior to startup.**
14. **Documented maintenance and inspection programs that ensure facility integrity.**



Technician at Henkel's Harrison, N.J., manufacturing facility checks transmitters sending information about flow, temperature, and product level to plant's computer controls.

tional Safety & Health Administration (OSHA), 29 CFR 1910.119, passed on Feb. 24, 1992, and aimed at preventing release of hazardous substances in the workplace and protecting worker health and safety. The OSHA rule is a performance-based standard that, among other things, requires companies to perform hazard assessments; develop written safety and operating procedures and provide training to employees; establish procedures to manage changes to chemical processes; conduct pre-startup safety reviews; and investigate incidents that resulted or could have resulted in accidents. OSHA believes the standard—estimated to cost more than $863 million per year for the first five years—will affect over 25,000 sites and 3 million employees nationwide.

Also last month, CMA's board of directors moved a step closer to adopting a measurement system called Prospect to track process safety performance in the association's member companies. Prospect may put new teeth in CMA's Responsible Care program, requiring members to file incident reports relating to process safety each year. The board met Oct. 25 to hammer out details and establish thresholds for incidents such as fires and explosions, releases, and injuries that would be reported. Although many in industry had expected Prospect to be approved in October for startup in 1994, the system has not yet been approved, and discussions will continue in January at CMA's next board meeting.

Responsible Care is one of several initiatives in addition to the OSHA PSM standard and proposed EPA risk management rule to be established over the past few years in response to public concerns about the impact of chemicals on safety, health, and environmental quality. A series of tragic international events in the 1970s and 1980s—at Flixborough, England; Bhopal, India; and Seveso, Italy—followed by a rash of major incidents in recent years in the U.S.—among them, the Phillips 66 explosion in Pasadena, Tex., in 1989 and the Arco Chemical, Channelview, Tex., blast in 1990—spurred the development of legislation and new programs to improve the safety performance of the chemical industry and its responsiveness to public concerns.

Responsible Care encompasses six codes of management practices covering Community Awareness & Emergency Response (CAER), Pollution Prevention, Process Safety, Employee Health & Safety, Distribution, and Product Stewardship. All CMA members—some 185—participate in the program.

In September 1990, the Process Safety Code became the third Responsible Care code of management practices to be adopted by CMA. It is aimed at preventing fires, explosions, and accidental chemical releases. According to CMA, the code is based on the principle that facilities will be safe if they are designed according to sound engineering practices; are built, operated, and maintained properly; and are

15. Sufficient layers of protection to prevent escalation of a single failure to a catastrophic event.

16. Provision for control of processes/equipment during emergencies resulting from natural events or utility disruptions.

PERSONNEL

17. Identification of skills and knowledge necessary to perform each job.

18. Establishment of procedures and work practices for safe operation and maintenance.

19. Training for all employees to reach and maintain proficiency in safe work practices prior to work assignment and in skills needed to perform job.

20. Demonstration and documentation of skill proficiency prior to work assignment and periodically thereafter.

21. Programs to ensure that employees in safety-critical jobs are fit for duty and not compromised by external influences, including alcohol and drug abuse.

22. Provisions that contractors either have programs for their own employees consistent with this code or are included in the member company's program, or combination thereof.

Source: Chemical Manufacturers Association

Tragic events of two decades spur efforts to improve process safety

INCIDENTS ABROAD:

1974 Flixborough, England
Twenty-eight deaths resulted from the explosion of a cyclohexane vapor cloud released when temporary piping failed at the Nypro facility.

1976 Seveso, Italy
Thousands affected by dioxin release from runaway reaction at Icmesa plant, owned by Hoffmann-LaRoche subsidiary.

1984 Cubatao, Brazil
Some 508 people killed in shantytown built over swamp where 700 tons of gasoline leaked from ruptured pipe and ignited.

1984 Mexico City
An explosion and fire at a liquefied petroleum gas facility in San Juanico suburb killed 542, injured more than 4,000.

1984 Bhopal, India
More than 2,000 deaths and hundreds of thousands affected by a massive leak of methyl isocyanate from Union Carbide facility due to runaway reaction after water contaminated a tank.

1986 Basel, Switzerland
A spill of 30 tons of pesticides from Sandoz plant went into the Rhine.

1987 Ros Al Juaymah, Saudi Arabia
Vapor cloud explosion at the natural gas complex reportedly killed as many as 22 and injured 15 others.

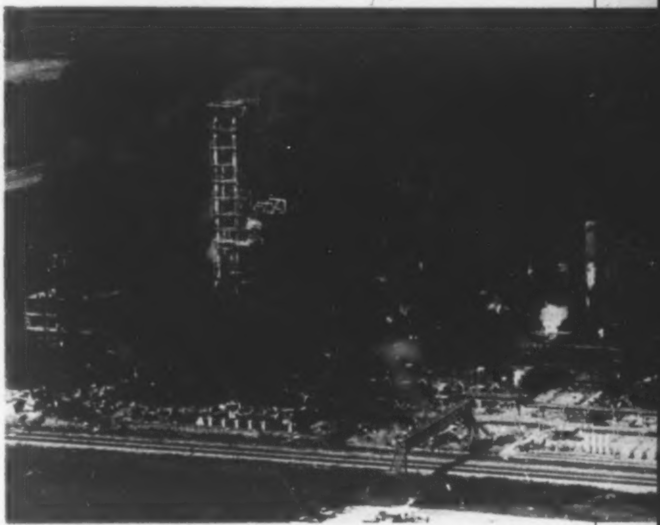
1993 Frankfurt, Germany
Explosion in polyvinyl alcohol plant killed one and injured one at Hoechst works.

INCIDENTS IN THE U.S.:

1985 Institute, W.Va.
Vapor cloud of aldicarb oxime and methylene chloride from a Union Carbide plant injured 135.

1987 Texas City, Tex.
Vapor cloud of hydrofluoric acid from Marathon Oil refinery drifted through community; 1,000 received medical treatment.

1988 Henderson, Nev.
Ammonium perchlorate explosion at Pepcon killed two and injured 350.


Houston Chronicle photo

Phillips 66 explosion in Pasadena, Tex., killed 23, injured 132.

1989 Pasadena, Tex.
Cloud of ethylene and isobutane exploded at Phillips 66 plant, killing 23 and injuring 132.

1990 Channelview, Tex.
Wastewater tank at Arco exploded, killing 17 and charring an area the size of a city block.

1990 Cincinnati, Ohio
BASF resins plant explosion left one dead, 71 injured.

1991 Charleston, S.C.
Albright & Wilson Americas phosphorus chemicals plant explosion killed six, injured 33.

1991 Port Lavaca, Tex.
Blast at ethylene oxide unit in Union Carbide's Seadrift plant killed one, injured 19.

1991 Sterlington, La.
Eight deaths, 128 injuries from explosion and fire at IMC Fertilizer facility.

1991 Corpus Christi, Tex.
Hydrofluoric acid vapors at Kerr-McGee plant killed two workers.

periodically reviewed for conformance. The code identifies areas in which companies can improve their safety performance, from process design through operation and routine maintenance.

Many in the industry say the Responsible Care philosophy has become the key to survival in today's tough economic and regulatory climate. And many are working to implement comprehensive management systems that address Responsible Care, the OSHA rule, the anticipated EPA rule, and quality management goals simultaneously.

Assessing how much progress actually has been made, toward improving process safety in general, and implementing the Responsible Care Process Safety Code in particular, is not an easy task. Statistics collected by government agencies on such indicators as injury rates and fatalities are only indirect and rather imperfect measures of safety in the chemical industry. Some believe the statistics may obfuscate more than elucidate the industry's track record. Responsible Care's self-evaluation scheme has been criticized for lacking a means of independent, external validation, leading some to dismiss the entire program as a "public relations folly."

While government agencies and other groups such as CMA struggle with improving the measurement tools used to track and evaluate safety, evidence is mounting that recent progress toward implementing the Process Safety Code is more than just hype.

Nonetheless, the industry has many challenges to tackle. Because of OSHA's PSM standard, the cost of compliance is already high; the new EPA rule will certainly raise the cost higher still and the effect of increased regulations on small businesses remains to be seen. Many smaller operations are banding together in networks, sharing resources, ideas, and personnel in an effort to cope.

Vulcan's plant at Geismar, La., lights up night sky.

Meanwhile, companies are examining how to design safety features into plants at the outset, rather than adding them on after the fact, much the same way companies are looking to prevent pollution by turning to environmentally benign syntheses and processes. Another focus of attention is designing management systems capable of ensuring that safety standards are met every day, not just during periodic snapshots at audit time. Part of the solution will be to get a better handle on the causes of human error. And continuing to improve communications with the public, especially with the EPA risk management rule looming ahead, seems to be on nearly everyone's mind.

Rules of the road

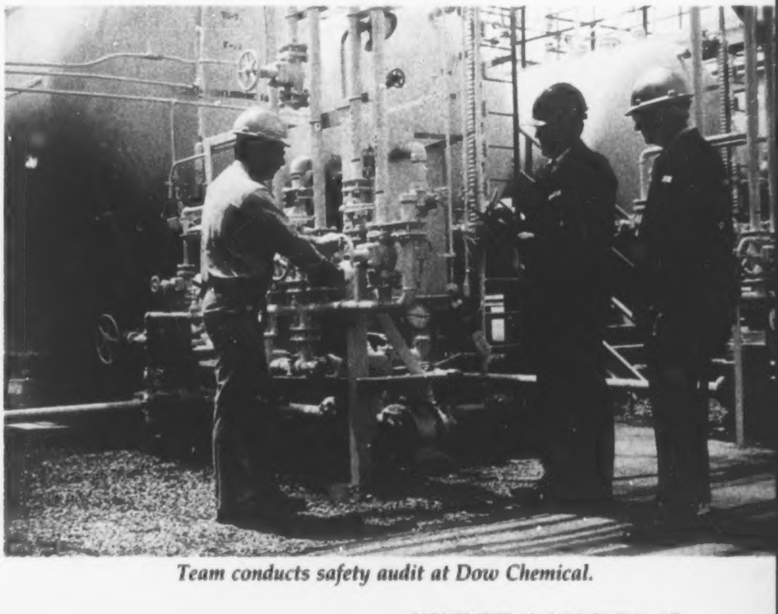
It's hard to talk about implementing the Responsible Care Process Safety Code without mentioning in the same breath the OSHA and proposed EPA rules. That's because many companies are leveraging their efforts by adopting a single, unified approach to managing process safety, product quality, and environmental protection. "There's a synergy between the Responsible Care codes, the OSHA standard, the EPA regulations, and quality programs such as ISO 9000," notes Irene L. Jones, coordinator of health and safety at Texaco Chemical in Houston.

DuPont, for example, has written a corporate guideline for process safety management that embraces Responsible Care codes, the OSHA and proposed EPA rules, guidelines of the Center for Chemical Process Safety (CCPS) of the American Institute of Chemical Engineers (AIChE), and quality management principles. Explains Arthur F. Burk, senior safety fellow at DuPont: "It's the way we implement the Responsible Care code."

Ray E. Olsen, chief safety engineer at Exxon Chemical, Baytown, Tex., says Exxon is "fully committed to implementing the code on a worldwide basis under a single management system." Many companies observe that a single system creates efficiencies and helps save precious time and resources.

"With so many activities going on in the chemical industry—downsizing, reengineering of plants, quality programs, and implementing the process safety standards—companies' resources are stretched tight," says Winfield S. Person, director of regulatory affairs at Henkel, Gulf Mills, Pa. "It's a matter of how much you can do with finite resources. The amount of work that the regulatory agencies are putting on industry is almost an overburden."

Many companies have been working actively to anticipate the new rules of the road. "Early on, we tried to develop a set of division guidelines that address both the OSHA rule and the Responsible Care Process Safety Code simultaneously," says Bradford T. Clement, division health and safety supervisor at Vulcan Chemicals in Birmingham, Ala.


Team conducts safety audit at Dow Chemical.

Process hazard analysis is costly and painstaking task

The Occupational Safety & Health Administration standard on process safety management and the proposed Environmental Protection Agency risk management rule require many companies to carry out some form of process hazard analysis. It is estimated that as many as 140,000 plant sites in the U.S. will conduct one or more of these analyses by 1997.

The Hazard & Operability (Hazop) study is one of many methods used to systematically review the design and operation of a facility to identify hazards. A study team is assembled, typically consisting of process and control engineers and operations, safety, and maintenance representatives. The team identifies all potential deviations from normal safe operation that might lead to any safety hazard or operating problems.

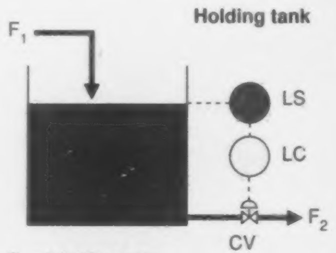
Before a Hazop study begins, documentation on everything from piping and instrumentation diagrams to sequence and interlock descriptions must be updated and verified.

During the Hazop study, one segment of a system is analyzed at a time. The team applies a set of guide words such as "more" or "less" to process parameters like "temperature" or "flow rate." The guide words help team members envision potential effects when off-normal conditions occur. Deviations and their hazardous or significant consequences are recorded in a log sheet, along with recommendations on how to prevent the event or improve safety. The team continues to review the process, one segment at a time, until the entire system is finished.

Hazop guide words and their definitions

Word	Definitions and examples
No/not	Complete negation of the design intent; no flow in a pipe.
More/less	Quantitative increase/decrease of process variable such as flow rate, temperature.
As well as	All design intentions are fulfilled and something happens in addition.
Part of	Only part of intention is fulfilled; batch reactor is only partly cooled, leading to runaway reaction.
Reverse	Logical opposite of design intention; reverse flow of material, electrical current, control signal, chemical reaction (that is, decomposition).
Other than	Something completely different from intention; tank car of acid is unloaded into caustic storage tank.

A simple example to illustrate the Hazop methodology was described by Sanjeev Mohindra and Thomas C. McKelvey of DNV Technica Inc., Columbus, Ohio, at a recent meeting of the American Institute of Chemical Engineers (AIChE). The example involves a holding tank with inlet flow F1 and outlet flow F2. The liquid level in the tank is monitored by a level sensor and is maintained by controlling



F_1 = Inlet flow rate
F_2 = Outlet flow rate
LS = Level sensor
LC = Level controller
CV = Control valve

"Safety has always been a strong focus in the company, but the efforts to formalize and extensively document procedures are new as a result of the OSHA rule and Responsible Care."

DuPont's Burk sees the Responsible Care code and the new government regulations as complementary. "Not only must companies comply with the regulations, but the Responsible Care code urges companies to go beyond and to show continuous improvements," he notes.

Vincent E. Boyen, director of safety and health at Mallinckrodt, St. Louis, agrees. "While there is some overlap between the code and the OSHA rule," he points out, "the Responsible Care code is not chemical specific; it emphasizes the management leadership and personnel issues perhaps more."

So whereas Responsible Care provides a guiding philosophy of continuous improvement in process safety, the OSHA rule outlines specific requirements that employers must meet. The OSHA rule applies to facilities handling any of more than 130 listed toxic chemicals above a threshold amount, or to those that contain more than 10,000 lb of flammable chemicals. Specifically, employers must:

- Develop and maintain written safety information.
- Perform a workplace hazard assessment, including potential sources of accidental releases.
- Consult with employees in carrying out hazard assessments and accident prevention plans.
- Establish a system to respond to hazard assessment findings.
- Periodically review the hazard assessment and response system.
- Develop written procedures for safe operation of processes.
- Provide information and training to employees in those procedures.
- Ensure that contract employees receive appropriate information and training.
- Train employees and contract employees in emergency response procedures.
- Establish a quality assurance program to ensure that equipment is fabricated and installed in a manner consistent with design specifications.
- Establish maintenance systems to ensure ongoing mechanical integrity.
- Conduct pre-startup safety reviews of all equipment.
- Establish procedures to manage change.

Excerpt of Hazop log sheet for holding tank

Guideword	Cause	Consequence	Safeguard	Recommendations to improve safety
No flow	1. Tank empty 2. Line 2 plugged 3. Line 2 rupture 4. Control valve CV fails closed 5. Controller LC failure causes valve to close 6. Level sensor LS reads low 7. Error in signal fed to controller LC 8. Incorrect level set point causes valve CV to close	Operational problems Level in tank increases		Install flow meters on lines 1 and 2
Less level	1. Flow F_1 less than normal 2. Flow F_2 more than normal 3. Leak in tank 4. Incorrect level set point	Outflow reduced		
More level	1. Outlet of tank blocked 2. Inflow to tank greater than normal 3. Outflow from tank less than normal 4. Incorrect level set point	Potential for overflow of the tank	High-level alarm will alert operators to the problem	Install redundant high-level alarm as backup

outflow through a valve. Guide words for this process in the Hazop study would include no flow, less flow, more flow, reverse flow, less level, and more level.

For each guide word, team members would enter potential causes and consequences of the condition into the log sheet. For example, "more level" might be caused by the tank outlet being blocked, potentially causing a tank overflow. Process improvements suggested by the team—for example, installing a backup high-level alarm in the tank—are also entered into the Hazop log sheet.

Now imagine a large, complex chemical plant, and the time and effort required to conduct a Hazop study. "At Monsanto, a typical Hazop [study] of a large process system will take many weeks to complete," according to Monsanto senior fellow Raymond A. Freeman of the company's engineering department in St. Louis. The study team will meet three or four times per week for up to six hours at a stretch. Because Hazop studies are so time-consuming and labor-intensive, Freeman and his coworkers have developed an expert system that can help budget time and resources for the task.

Freeman also is working to build safety into the process at the design stage, as a new process comes out of the R&D lab and before it is scaled up. A new technique, called interactive matrix review, brings the chemist, safety engineer, and lead process engineer together in a systematic study to anticipate and prevent potential hazards associated with a new process.

Hazop studies and interactive matrix reviews are but two of a wide range of techniques for process hazard analysis, many of them described in a guidebook, "Guidelines for Hazard Evaluation Procedures," published by AIChE's Center for Chemical Process Safety.

- Investigate every incident that results in or could have resulted in a major accident in the workplace.

One of the most labor-intensive and time-consuming requirements of the new OSHA rule is preparing for and carrying out a hazard analysis—a systematic procedure to identify, evaluate, and control hazards in industrial processes. The Hazard & Operability (Hazop) study is one of many procedures used for this purpose.

In the Hazop method, a study team is assembled, typically consisting of process and control engineers and operations, safety, and maintenance representatives. The team identifies all potential deviations from normal safe operation that might lead to any safety hazard or operating problems and recommends improvements to the process.

Before a Hazop study can even begin, however, documentation on everything from piping and instrumentation diagrams to sequence and interlock descriptions must be updated and verified. Documentation must include every valve, sensor, and pipe in the system. "For a complex facility, it is not unusual to spend several man-months and more than $100,000 to update and verify documentation prior to a Hazop study," says Raymond A. Freeman, senior fellow in the engineering department of Monsanto in St. Louis.

DuPont's Burk observes that the work doesn't stop there. "It may take hundreds of man-hours to complete a hazard analysis for one process at a plant, anywhere from 200 to 800 man-hours is not uncommon. Our largest sites may have 30 to 40 regulated substances, many of them in more than one process."

But like the adage, "no pain, no gain," many acknowledge the benefits of satisfying the new standards—even companies like DuPont that have been heavily committed to safety all along. "The new OSHA rule helped all of our sites to focus on improving the quality of our implementation of the process safety management standard—things like improving documentation, training, and understanding at all levels about process safety," says Burk.

The cost of the new safety standards may be high, but Vulcan's Clement says the company "expects to receive benefits in terms of even safer and more reliable plants and equipment." Several years ago, recognizing what would be required in the future, Vulcan launched a major effort to update process flow diagrams and documentation, says Clement. Initiated four years ago, the effort is now paying off in terms of implementing the new safety codes.

Robert W. Ormsby, principal engineering associate in the

Designing instrumentation with safety in mind is goal at Henkel.

corporate safety department of Air Products & Chemicals, Allentown, Pa., cites a similar experience: "Process safety has been an important part of the culture at Air Products. Back in the mid-1970s, the company committed to being a leader in safety. Between 1978 and 1992, Air Products had a threefold reduction in recordables and a fivefold reduction in lost-time injuries as a result of our attention to safety."

Recently, the company's plant in Pasadena, Tex., received an award for successfully managing safety during the construction of a new 75 million-lb-per-year polyvinyl alcohol plant, completing more than 1.1 million worker hours with zero lost-workday cases and only six recordable injuries.

Ormsby adds, "The company embarked on a program to educate scientists and engineers in process hazard analysis. Some 2,600 people in the company have received training in those techniques. So when the Responsible Care Process Safety Code came out in 1990, the company had a solid approach to process safety management already in place."

A process hazard analysis is also one element of the proposed risk management program recently released by EPA. Ormsby observes that "the proposed EPA plan extends the spirit of the OSHA standard beyond the fence line, and many aspects of the management system aimed at meeting the OSHA requirements should be transferrable to the risk management rule."

The EPA rule would require facilities to:

- Develop and implement a risk management program, including a hazard assessment, prevention program, and emergency response program. The hazard assessment would include off-site consequence analysis, including the worst case scenario, and a five-year accident history. The prevention program would consist of a process hazard analysis and other elements similar to the OSHA rule.
- Develop and submit to the Chemical Safety & Hazard Investigation Board, along with local emergency planning committees and other local bodies, a risk management plan that would summarize the off-site consequence analysis; list the major hazards and steps being taken to address them; and provide a five-year accident history, a description of the emergency response program, and a description of the facility's safety management system.

Outlined in the proposed EPA rule are some of the similarities and differences between the risk management plan and the OSHA standard. Obviously, OSHA's focus is on workplace impacts, whereas EPA's focus is on off-site consequences, reflecting the different statutory mandates of the two programs. The main differences are the off-site consequence analysis, the five-year history, and public disclosure of the plan. And although the lists of regulated substances are similar but not identical, EPA says, "The elements and language of EPA's proposed ... program are, to the maximum extent possible, identical to the parallel elements in OSHA's process safety management standard."

EPA estimates that more than 140,000 facilities would be affected by the proposed rule, of which 87,800 would also be covered by the OSHA rule. "The total universe of covered facilities includes 22,935 manufacturers; ... 3,360

Ormsby (left): safety is paying off. Person: committed to the code

Community advisory groups help Responsible Care come alive

Diane B. Sheridan, a member of the Chemical Manufacturers Association's Public Advisory Panel, is actively involved with several local groups working to facilitate community-industry communication.

Sheridan gives examples of the impact that community advisory groups can have on:

ACCOUNTABILITY

"One of the biggest changes a community advisory panel makes in a plant is in terms of accountability. Having to report releases, whether planned or accidental, having to respond to concerns and complaints, having to justify not doing something the community expected during an emergency—all of these are done face-to-face with people the plant manager is going to see again and again.

"The public gains a face in a community advisory panel, and that makes the plant manager accountable in a different way than ever before. In time, the plant management and workers come to ask themselves 'What would the public think?' while going about their daily activities, thereby bringing public concerns into the daily operations in a subtle way."

WARNING SYSTEMS

"While some plants have had emergency warning systems in place, others were spurred to make them a reality by input from their community advisory groups":

- Pasadena Citizens' Advisory Council urged all plants in its area to chip in to purchase a siren system and lobbied in support of a request to the city to set up and maintain a warning system.
- The Community Advisory Panel to Lyondell and Arco urged installation of a warning system and outlined a program to ensure that people know about its existence and what to do if the sirens sound. In addition, they asked for use of a radio channel to notify the community of noticeable nonemergency events such as flares, odors, noises, and construction. This is in addition to more frequent use of the Community Awareness & Emergency Response hotline and local media to announce such activities.
- After fires at two plants lit up the night sky in 1992, the Texas City/LaMarque Community Advisory Panel demanded that plant managers as a group work with the cities to improve communications when there is not an emergency but it looks to nearby residents like there is one. The panel offered dozens of ideas for doing so. The city found that the local radio station was glad to publicize activities ranging from flares and odors to drills and pipeline flaring.

Sheridan: facilitating communication

EMISSIONS REDUCTIONS

"When panels decide which chemicals concern them most, plants learn either directly or by inference where to focus reduction efforts."

- Vulcan Community Involvement Group's dogged dialogue about the need for emissions reduction and the community's concerns about deep-well disposal have been acknowledged by the company as the impetus for a variety of emissions reduction projects.
- An odor that caught the attention of many people last spring was discussed at a Texas City/LaMarque panel meeting. The investigation undertaken by the plants led one of them to identify the source and to accelerate plans to repair and replace equipment in order to reduce the possibility of a reoccurrence.

PLANT TOURS

"Plant tours are popular but it can be a challenge to make them meaningful for the public."

- Vulcan Community Involvement Group toured a new unit under con-

private utilities (electric and gas utilities, drinking water systems, and [water] treatment works); 33,250 public drinking water and treatment works; 50,000 cold storage facilities; 9,460 wholesalers; 20,000 propane retailers; and 1,240 service industry facilities," according to the proposed rule.

EPA further estimates the first-year cost of the proposed rule would be $503 million and estimates a saving in terms of environmental damage, human impacts, and response actions totaling $890 million in the first year.

The agency will hold three public hearings in the coming year to receive feedback about the proposed rule, the first of which will be in Washington, D.C., on Nov. 30. Some of the discussion will no doubt center on the definitions of worst case scenario. The proposed rule defines "worst case release" as "the instantaneous loss of all of the regulated substance in a process, with failure of all mitigation systems (active and passive)."

Consequence analysis of a worst case release would be required to estimate the possible rate and duration of release, quantity released, and the distances in any direction that the substance could travel before it dispersed enough to no longer pose a hazard, under average as well as worst case weather conditions. Industry may have some qualms about this aspect of the proposed rule. Ormsby speculates that "the industry will have some challenges to explain the calculations about worst case events to the public."

Good things take time

Although commitment to the Responsible Care philosophy appears to be high, actual progress toward implementing the Process Safety Code seems to lag.

At Henkel, "it's been slower than we wanted it to be," says Person. "We have a strong belief in the Responsible Care initiative. We endorse it and are committed to complying with the codes." Responsible Care activities at Henkel are managed at the vice president level through a team of representatives from each of five operating divisions.

Pasadena citizens' council and industry liaisons study health effects of listed chemicals.

struction almost one-on-one with the plant personnel who will work at that unit. The one-on-one method ... let them get into a lot more detail than often occurs with group tours.

- Pasadena Citizens' Advisory Council, which includes several educators, asked the plants to set up in-service training for science teachers. Visits focused on lab safety, including handling of old chemicals and fighting of small fires.
- Two panels have taken tours related to detecting fugitive emissions. The Texas City/LaMarque panel saw a laser device detect emissions invisible to the naked eye. The device is being developed to help control emissions of specific chemicals.

COMMUNICATIONS

"Every panel struggles with getting information out to the community about its existence and purposes. Communicating about what they learn is a challenge for panels because they would like more people to know what they now know, but they don't want to be seen as an industry cheerleader or spokesman."

- The Deer Park Community Advisory Council gained the support of the local newspaper for publication of a page of industry-related news on expansions, noticeable events, and releases.

Companies that sponsor the community advisory groups referenced by Sheridan include:

Community Advisory Panel to Lyondell and Arco, Channelview, Tex., on north side of Houston ship channel: Arco Chemical, Lyondell Petrochemical.

Deer Park Community Advisory Council, Deer Park, Tex.: Geon, Hampshire Chemicals, Intercontinental Terminals, Lubrizol, Occidental Chemical, Paktank, Rohm and Haas Texas, Rollins Environmental Services, Shell Deer Park Manufacturing Complex.

Pasadena Citizens' Advisory Council, Pasadena, Tex., formed by members of the East Harris County Manufacturers Association Pasadena Outreach Group, including some non-CMA members (six plants rotate as liaisons): AES Deepwater, Air Products, Aristech, Crown Central Petroleum, Enron, Ethyl, Georgia Gulf, Gulf Coast Waste Disposal Authority, Houston Lighting & Power, ICI Americas, Kaneka Texas, Kerley AG Products, Lyondell-Citgo Refinery, Mobil Mining & Minerals, Occidental Chemical, Oxy Petrochemical, Phillips, Safety Kleen, Simpson Pasadena Paper.

Texas City/LaMarque Community Advisory Panel, Texas City, Tex.: Amoco Chemical, Amoco Oil, ISP, Marathon Refinery, Phibro Energy USA, Sterling Chemicals, Union Carbide.

Vulcan Community Advisory Group, Wichita, Kan.: Vulcan Chemicals.

The company's 22 plants vary in their implementation stage, like most other companies in the industry. The pace varies and it doesn't happen overnight, Person says, adding that the company's incident rate is close to the average for its cohort of midsized CMA companies, but its goal is to do better.

CMA member companies conduct an annual self-evaluation of the code of management practices, including those dealing with process safety. The six stages of implementation of the management practices under the Responsible Care code, from lowest to highest, are 1—no action; 2—evaluating existing practices; 3—developing plan to implement management practice under Responsible Care code; 4—implementing plan; 5—management practice in place; and 6—reassessing management practice implementation.

Even companies that have been making safety a priority for many years are struggling to make faster progress toward implementing the Process Safety Code. John W. Oldner, corporate director for safety, loss prevention, and security at Dow Chemical in Midland, Mich., points out that "Dow's been actively working on safety for decades, and we're not there yet." The company average for sites in the U.S. is shy of level 5—"somewhere around 4.7," he says. That's an average based on more than 30 sites, but the sites vary considerably in size and complexity.

In Freeport, Tex., for instance, one Dow site has 80 plants inside the fence, but only one plant is sampled in calculating the company's average implementation level. Other, smaller sites, which are not as far along in implementation of the code, tend to bring down the overall average. But Oldner emphasizes that given finite resources, the company has to allocate them where they'll do the most good.

Person says that Henkel has developed a "tough scale" for measuring performance against milestones that must be met before a plant can proceed to the next level of code implementation. "The process is slow because we are accurate in measuring where we stand. This system of requirements is done for all of the Responsible Care codes," he explains.

Vulcan Chemicals' Wichita, Kan., plant (left). Fish: safety record better than CMA average

Henkel's plant in Charlotte, N.C., employs nearly 200 people, and makes specialty products for the paper, textile, coatings, and ink industries. Safety manager Frank Calloway notes that implementing the Process Safety Code is especially time-consuming for older plants, which require a lot of effort to get old documentation in order.

Calloway says the company has completed hazard reviews there, as well as procedures for incident investigation, management of change, and contractor programs, and has hard-wired the redundancy and backups to improve safety.

The human element is a key part of Henkel's program. "It's critical to spend time training plant operators," Calloway says. "Early buy-in on the part of these people is essential. Spending time up front with them will smooth implementation of the code. You need to build in performance goals for process safety for operations personnel, just like any other performance goals."

Calloway observes that a large part of process control is people control. "We spend a lot of time looking at the causes of human errors, and making sure that things like instrumentation displays and alarm locations are optimally designed with safety in mind. The older processes tend to have less instrumentation and are more labor-intensive. You really have to scrutinize them for potential causes of human error," he says.

The Charlotte facility has a number of batch reactors that are used for different reactions at different times. "Multiple-use vessels create different kinds of risks for each type of reaction. It means our Hazop studies are more complicated—we have to do a new study for each type of reaction, and the reaction mixtures tend to be more complex," Calloway observes.

"The record keeping and documentation can really swamp you," he says, but he points out that there are many advantages to the management-of-change element of the code that offset the paperwork burden: "The side-benefits are that it really makes you look before you leap. And it's a valuable tool for evaluating how a system has evolved over time, giving you a historical record of what changes were made and when, and how the various changes might have combined to produce new effects."

Henkel has upgraded the ethoxylation unit at the Charlotte facility. A Hazop study of the unit helped operators to better understand the process and new procedures before their final operation training, according to unit operator Ron Spencer.

Following completion of the upgrade, plant personnel carried out a pre-startup safety review, updated the emergency response plan, and provided information on the unit to local emergency officials. A comprehensive operator certification training program has now been implemented for all manufacturing personnel at the site. And the management-of-change system has been applied to the entire location to ensure that changes in processes are safe for all production units, say company officials.

George L. Fish, Vulcan Chemicals vice president for R&D, engineering, and environmental health and safety, is the Responsible Care coordinator for that company. He says Vulcan tracks implementation of all 22 management practices and computes an overall average, which currently is just below stage 4 (implementing the code).

Fish says the company's track record on safety is "better than the CMA average." Indeed, one Vulcan facility, the chlor-alkali plant at Port Edwards, Wis., was cited in August for a record 25 years of operation without a lost-workday accident.

William G. McGlasson, director of environmental services at Olin Chemicals Division in Charleston, Tenn., reports that Responsible Care is a "far-reaching initiative that extends throughout the entire organization in [the] chemicals division." He says it combines existing programs in safety, health, and the environment, and builds upon the safety program instituted in the 1960s.

"Our current safety records speak for themselves," says McGlasson. "Our monthly recordable incidents from December 1990 to May 1993 continue to show positive reductions," dropping from over 4.4 to 2.7 during that period. McGlasson further reports that the level of implementation of the Responsible Care Process Safety Code has increased

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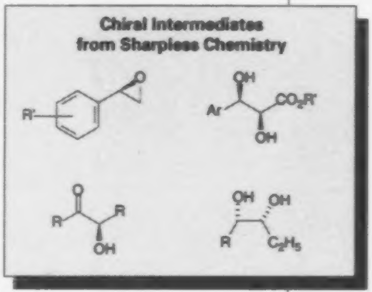

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CIRCLE 13 ON READER SERVICE CARD

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Olin's Charleston, Tenn., plant conducted its eighth annual safety drill this year with an exercise that simulated a chlorine pipeline leak. Observers from participating agencies critiqued the drill.

in each of the company's three divisions from January 1992 to April 1993: going from 4.8 to 5.3 in basic chemicals; from 5.0 to 5.2 in performance chemicals; and from 3.7 to 4.7 in Olin Hunt.

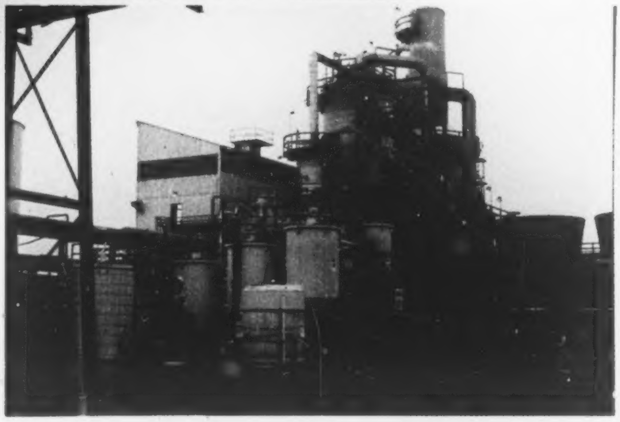
Community groups get involved

Part of implementing the Responsible Care Process Safety Code is getting the public involved through local community advisory groups. The community group at Vulcan's Wichita, Kan., facility seems to be one of the most extensively involved in plant operations anywhere. Gene Meyer, environmental, health, and safety manager at the plant, tells C&EN that representatives from the company's community group have even been involved in a Hazop study.

It all started in the group's monthly community meetings, where Vulcan representatives discussed the company's plans to build a sodium chlorite plant and described the Hazop study that would be done in the course of preparations. The community involvement group members wanted to understand the Hazop process better, so several attended sessions of the two- to three-week-long study. After the Hazop was completed, the company explained to the group how outcomes of the study resulted in safety improvements.

George Potts, biologist, environmental consultant, and former faculty member at nearby Friends University, participated in the Hazop study. Potts, a community involvement group member for more than four years, sat in on

Weyerhaeuser Company
CHLORINE PLANT



Sims (above): setting priorities, networking are key for small business. Weyerhaeuser's chlor-alkali facility at Longview, Wash.

about two hours of the Hazop study. In just that short time, he says, two or three items came up that resulted in a change in the way things would be run—and that was only a small fraction of the entire study. Potts believes a Hazop analysis can have a significant impact on plant safety.

Anneke Allen, associate professor of chemistry at Wichita State University, also attended portions of the Hazop study. She says, "It's been a good experience. Vulcan's efforts to clean up the facility have been impressive. The Hazop process worked out well."

Air Products has set up community advisory panels at 10 of its 15 chemical manufacturing sites. One of its most active groups is associated with the company's Escambia Plant in Pace, Fla., near Pensacola. The facility has seven plants on a total of 1,500 acres, of which 500 acres are industrialized, 100 acres are an ecological sanctuary, and 900 acres are an undeveloped buffer zone.

Richard H. Sroufe, environmental superintendent at the Escambia plant, describes activities of the panel that led to the formation of a telephone alert system. Paid for by seven industries in the region, the system is countywide and now can be used even for natural disasters. It was used in two recent events, a flood and a natural gas leak, according to Sroufe. Emergency response plans may call for people either to evacuate or to take shelter where they currently are. Because many people didn't know the proper procedures, the panel developed a training video that is now shown at schools and to civic groups.

Sroufe has worked at the plant for 19 years. Over the past few years, he points out, a much more open relationship with the community has evolved. "It used to be that people didn't know anything about what's happening on the site," he says. "Today, if someone asks a question about the plant, we invite them in. There are tours by the public of the sanctuary grounds. The way we relate to the community has changed."

The opportunity to meet with community members is an important element of the Responsible Care code to Jones at Texaco Chemical. "We can't do enough of this," she stresses.

Jones adds that the new process safety codes have provided incentive for companies to work together more than ever before to ensure safety standards are met. "Openness is more a part of our business now than it was in the past," she observes. For example, in the Jefferson County area of Port Arthur/Port Neches, Tex., some of Texaco's equipment is located on other companies' sites, and vice versa. A couple of years ago, technical and operations people from Texaco met with their counterparts from those companies to identify potential hazards and to establish responsibility for mitigation. "It was a very positive experience," says Jones. "Besides sharing the responsibility, the companies are sharing in the benefits of safety activities."

Small business bears up

Under the new rules of the road, many small businesses are now or will be establishing process safety management programs. With limited technical and financial resources to bring to bear on the problem, however, many small firms are struggling to cope.

A technically underserved segment of a larger business may find itself in the same boat. For example, large packing houses that handle anhydrous ammonia as a refrigerant may be required to conduct a process hazard analysis but may not have the expertise to do so.

OSHA estimates that small businesses will bear a collective cost of $88.9 million per year during the first five years of the process safety management standard. Yet many believe that the benefits will outweigh the costs in terms of fatalities and injuries avoided. Eric J. Lohry, manager of operations at Nutra-Flo in Sioux City, Iowa, presented a case in point at the summer national meeting of AIChE in Seattle last August.

Lohry points out that the challenges faced by small businesses as they implement process safety management systems are different from those encountered in large firms. "Without multiple layers of management, decisions are often made quicker, making management of change more de-

Nutra-Flo's plant in Sioux City, Iowa. Lohry (right): small business is taxed

manding," he notes. And "the smaller the business, the more hats a given employee may need to wear. For example, a small manufacturing firm may not have a safety specialist on staff, relegating those duties to the plant manager or engineer."

And the corporate culture is different in small firms. "Many small businesses do not have the same emphasis on safety as larger ones," says Lohry, and they "often will not have formal operating procedures and training programs. This will make the documentation, training, and management of change provisions of the [OSHA] rule difficult to achieve." And the overall cost of developing a safety program will be higher as a percentage of profits in a small company, he contends.

On the other hand, small firms may have greater flexi-

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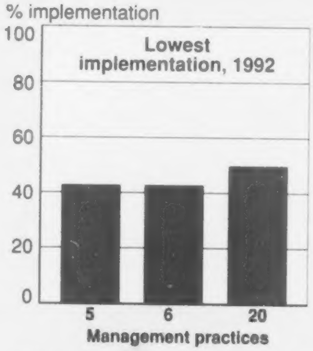
CIRCLE 9 ON READER SERVICE CARD

Progress toward Process Safety Code is higher for some management practices than for others

Member companies of the Chemical Manufacturers Association (CMA) conduct an annual self-evaluation of the codes of management practices, including the 22 practices dealing with process safety. The self-evaluations help members identify their strengths and weaknesses in carrying out Responsible Care. They also help CMA to identify areas where assistance for members is needed.

The six stages of implementation of the management practices under the Responsible Care code, from lowest to highest, are as follows: 1—no action; 2—evaluating existing practices; 3—developing plan to implement management practice under Responsible Care code; 4—implementing plan; 5—management practice in place; 6—reassessing management practice implementation.

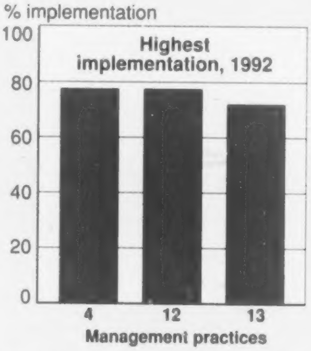
The charts show the percentage of member companies (more than 150 companies reporting) that are in the final stages (levels 4 to 6) of implementing the process safety management practices. Management practices with the highest and the lowest percentages of companies in the final stages of implementation are shown.



5. Sharing safety knowledge—sharing lessons learned about incidents with others

6. Use of Community Awareness & Emergency Response in design—considering public comments and concerns about process safety systems

20. Documentation of proficiency—demonstrating skill proficiency before work assignment



4. Incident investigations—investigating, reporting, and follow-up of each incident

12. Facility design, construction, and maintenance—using sound engineering practices

13. Facility reviews—safety reviews on new/modified facilities during design and before startup

bility within their workplaces than large ones, and may have the most to gain from compliance. While small businesses account for only about 10% of the total cost of compliance, their share of avoided fatalities may be higher. OSHA estimates that "21% of fatalities avoided and 9% of lost-workday injuries avoided will occur in small establishments."

As an example, Lohry describes the case of his own company, Nutra-Flo, a small chemical manufacturing firm specializing in fluid fertilizers, currently with about 70 employees. The business has been family owned for some 35 years. "The company is typical of many small manufacturers in that there are only two engineers and two chemists on the technical staff," he says. "As would be expected in a small facility, the managers and engineers handle the safety function as well as other functions" in the business. The company uses anhydrous ammonia, phosphoric acid, potassium chloride, and ammonium thiosulfate, among other compounds.

"Safety has always been emphasized strongly by management. Since the 1960s, regular safety meetings were held and training was provided," Lohry says.

But in 1990, a disastrous explosion killed two welders. "In that same year, OSHA printed its preliminary process safety management standard, steering the safety management of the company in a new direction," he says.

The company established a loss control department to handle safety training and auditing and developed the company's first safety manual, as well as systems for incident investigations and preventive maintenance. Hazardous operations were reviewed using AIChE's CCPS guidelines even before the OSHA rule became law. "Without question, the CCPS guidelines were the backbone of the company's process safety management efforts. Prior to these guidelines, a small company with limited resources would be taxed to find acceptable methods and procedures," Lohry emphasizes.

The end result was a dramatically improved safety record, says Lohry. "For the first time since records were kept, the company had no recordable injuries for the year following the implementation of the corporate loss control program. The company has received safety awards and after three years, bottom-line improvements are showing up from lower insurance premiums," he adds.

Some small companies are finding that setting priorities and establishing regional networks can facilitate the implementation of process safety programs in the face of scarce resources.

Jim Sims, plant manager at the Weyerhaeuser chlor-alkali facility in Longview, Wash., stressed at the AIChE meeting last August that "the implementation of Responsible Care at the small manufacturing facility can be accomplished, but the philosophy of the 'critical few' must be followed. A small facility must select the codes that will have the greatest impact." He adds: "If too many tasks are attempted at the same time, then substantial progress is rarely obtained. The 'critical few' for us were CAER, the Process Safety Code, and the Employee Safety & Health Code, because these codes have the greatest daily impact on how we run our facility and how we interact with the community—our employees, their families, and our neighbors."

The Weyerhaeuser chlor-alkali facility, with about 100 employees, manufactures chlorine and other inorganic chemicals. Although it is part of a much larger pulp and paper complex at Longview, Sims' operation was largely on its own when it came to implementing the Responsible Care codes. "Responsible Care was assigned to a plant employee along with other duties," he says. "Initially, the material coming from CMA was overwhelming—too much, too fast. The coordinator felt swamped." By prioritizing, and with the help of a regional mutual aid network, substantial progress was eventually made. "The network has been extremely valuable in learning what other people are doing, the mistakes, and the successes."

Judith A. Cichowicz, general manager of Northwest Field Services, a Seattle-based hazardous waste management and environmental remediation firm, explains more about the regional network Sims referenced. "In an era of reduced resources, mutual aid serves as a resource enhancement device, permitting you to do more with less by making available an objective peer group," she says.

Cichowicz observes that the economics and geography of the Pacific Northwest region added an impetus to form the network. "The chemical industry is not a major industrial force" in the region, which has a natural-resource-based economy and population centers widely separated by large distances.

A survey sent to plant contacts in Washington, Oregon, and Idaho—identified by means of a CMA database—helped target the topics relating to Responsible Care of highest priority for the mutual aid group. Process safety was second in priority after community advisory panels. At network meetings, attendees shared information about implementing the Process Safety Code, conducting Hazop studies, and communicating about risks.

"Through organization of a simple, quasi-formal network, chemical companies in the Pacific Northwest have moved closer to successful implementation" of the goals of Responsible Care, says Cichowicz. "The approach is inexpensive, cost effective, and transferable to other parts of the U.S.," she observes.

Taking stock of progress

To ensure that Responsible Care codes reflect real public concerns, they were reviewed at every step of the way by a national Public Advisory Panel. Some 15 members from different constituencies and regions have been working to broaden CMA's understanding of public concerns about the use of chemicals in society.

Panel member Press L. Robinson, chemistry professor and associate vice chancellor for academic affairs at Southern University, Baton Rouge, La., believes, "Responsible Care is a good first effort on the part of the chemical industry to change its image and the way it does business."

Robinson says when the Public Advisory Panel was started four years ago, he initially had reservations about being on the panel. "Was this an initiative to make actual changes in industrial practices or just a slick public relations campaign—were we being co-opted?" he asked.

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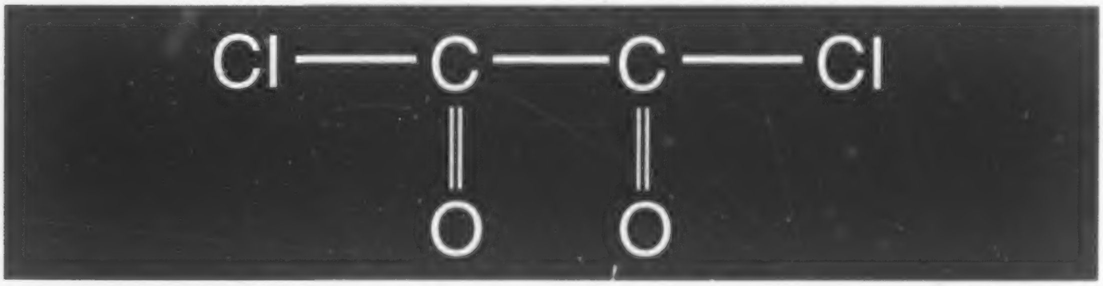
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CIRCLE 44 ON READER SERVICE CARD

"After a few meetings, I learned that the chemical industry was serious," he says. What convinced him? "Seeing our input actually get incorporated into the codes."

Panel members are donating a considerable amount of time and energy to this service, Robinson says. Members attend five meetings per year, of two to three days duration each. Although travel expenses are paid by CMA, no per diem, stipend, or honorarium is provided.

"I have been surprised that a group so diverse has been able to build consensus on the direction things should go," says Robinson. "Now, our posture is to monitor the implementation of the codes and see to it that genuine changes are made in industrial practices. External validation is extremely important. Self-evaluation by companies is a good start, but it won't convince the public."

What kind of report card would panel members give to the effort? "I'd give them a good C," says Robinson. "It's a great effort so far, but there's a whole lot that needs to be done. It's important to remember, though, that the situation wasn't created overnight, and it won't be solved overnight." He observes that the public tends to think that the chemical industry has deep pockets and has the money and other resources to solve anything. "Not so," Robinson asserts. "Changing the corporate culture is a tall order. From the board room to the shop floor, we're calling on people to understand, accept, and internalize the Responsible Care codes. Though the top levels of management are on board, selling the code to middle management and to the worker on the shop floor is the hardest part of the job."

Public advisory panel member Hoyt D. Gardner, physician and former American Medical Association president, says implementation is "proceeding as fast as expected." He was "initially curious as well as suspicious," when he first joined the panel, but now says he's "absolutely convinced that industry is not involved in Responsible Care just for a public relations campaign. The general public knows a public relations gimmick when it sees one. This is a day-in and day-out thing." One factor that convinced him was that panel members were given whatever information and access they asked for at the plants they visited, which included Rohm and Haas in Houston, Monsanto in St. Louis, and Kodak in Buffalo. "They weren't holding anything back," he says.

Panel member Diane B. Sheridan says, "Implementation seems to be moving along, but there is no way of telling for sure since a means of external verification is lacking." Sheridan lives in Taylor Lake Village, Tex., about 1.5 miles from an industrial plant. She says that throughout the region, there are now many community advisory panels; she serves as facilitator for several. Awareness in these communities has increased about health, safety issues, and emergency preparedness, and companies now are doing a better job of sharing information, she says.

Panel member Don Lesh of the Global Tomorrow Institute, Washington, D.C., says he was "very impressed at the results of what has been a careful and conscientious effort by CMA to develop and track each of the Responsible Care codes. It's been pleasing to see that things the panel has discussed get incorporated." But, he says, external verification remains a glint in the eye. And surveys have shown that employees on the shop floor "are not very aware of and/or involved in Responsible Care." Based on plant visits and meetings, the panel has sensed that commitment is

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CIRCLE 23 ON READER SERVICE CARD

Injury rates appear higher for smaller chemical firms

Injuries per 100 employees	Company size (employees) 1–19	20–49	50–99	100–249	250–499	500–999	1,000–2,499	2,500
1986	6.3	9.5	11.1	8.4	6.6	5.1	3.5	3.1
1987	5.8	9.8	12.2	9.0	6.5	5.7	4.1	3.9
1988	8.1	11.5	11.5	8.3	6.6	5.5	3.7	4.1
1989	6.7	10.4	11.2	8.5	6.9	6.1	3.5	3.7
1990	5.0	11.7	10.6	8.0	6.2	4.9	3.3	3.5
1991	6.9	10.1	9.4	8.2	5.1	5.6	3.5	3.2

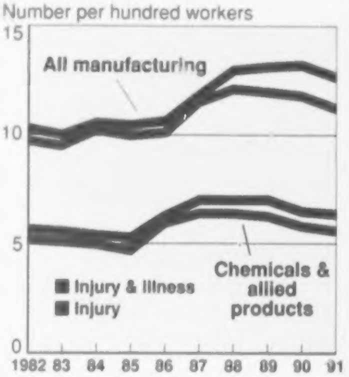
Source: Bureau of Labor Statistics

Fatalities in chemical and allied products industry triggered OSHA inspections

	1992	1991	1990	1989	1988	1987	1986	1985	1984	1983	1982
Number of inspections	23	41	28	33	23	41	30	33	27	37	30
Inspections with citations contested	8	7	8	10	10	12	6	5	6	5	4
Number of fatalities[a]	23	54	34	57	26	44	34	67	29	45	38
Number of violations:											
Willful[b]	13	0	93	3	1	11	1	6	1	6	0
Serious[c]	106	162	147	107	36	86	49	26	40	27	25
Total[d]	160	213	281	155	59	188	93	46	76	39	35

a Does not include data on contractors, and some fatalities may not have been reported. **b** Serious or nonserious violations for conditions known to exist. **c** Violations causing or likely to cause death or serious harm, and company knew or could have known of hazard. **d** Includes willful, repeat, serious, unclassified, other, and failure-to-abate violations. **Source:** Occupational Safety & Health Administration

Worker injury, illness rates head down



Note: Occupational injury is any injury such as a cut or fracture that results from a work-related event or from a single instantaneous exposure in the work environment. Occupational illness is any abnormal condition or disorder, other than one resulting from an occupational injury, caused by exposure to factors associated with employment, including acute and chronic illness or disease that may be caused by inhalation, absorption, ingestion, or direct contact. **Source:** Bureau of Labor Statistics

evident at chief executive officer and senior management levels, but not on the shop floor. "It's a major challenge for all companies," he adds.

Michael J. Wright, director of the health, safety, and environment department at United Steelworkers of America, Pittsburgh, Pa., believes there is room for improvement in bringing organized labor into the Responsible Care process, and remains skeptical whether CMA will get tough on companies that fail to comply with the code. "The jury is still out on Responsible Care. It depends upon voluntary compliance. How it gets implemented will be the real test." Because the form of implementation is at the discretion of the companies, Wright fears that some companies "may comply with the letter of the code, but not the intent."

Robert Wages, president of the Oil, Chemical & Atomic Workers International Union, Denver, also is skeptical. "I regard Responsible Care as a public relations folly. I've not seen any practical application of it," he says. As for the new OSHA process safety management standard, he is "still searching it out."

Wages believes there has been a lack of real input from the workers on how the process safety management standards are implemented inside the plants. "Industry is relying too much on outside consultants instead of the people inside the plants," he charges. Consultants lack site-specific knowledge, he believes, and bring only textbook knowledge to bear.

Wages fears that reinventing government may end up meaning the fox will guard the hen house: Instead of hiring enough OSHA inspectors, industries will contract out inspections or conduct inspections themselves.

He has more positive words about the increased participation by workers in hazard analyses. But overall, Wages believes that how industry will follow through on implementing the new process management standard in practice remains to be seen. "It's still unfolding," he says.

The OSHA rule is a performance-based standard, meaning that it defines what must be done, but not how. Both industry and labor have been uneasy about how OSHA will interpret the rule. In response to threat of a lawsuit, OSHA signed a settlement agreement with labor groups earlier this year that requires certain language relating to the rule to be spelled out in OSHA's next compliance directive, to be published "soon," according to the agency.

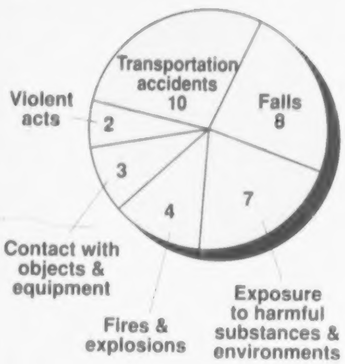
Among other things, the settlement statement specifies that process hazard analysis teams' recommendations are to be implemented unless an employer can document that an alternative will address the concerns at least as effectively and efficiently. Labor groups generally believe that companies should be obligated to implement the recommendations in order to ensure safety for workers. Many in industry, including CMA, have issued statements saying in effect that it is inappropriate to turn recommendations into imperatives, and that many factors must be weighed in addressing safety issues.

Safety report card: U for uncertain

They say the devil is in the details. In this case, it is the lack of detail in available data that bedevils any attempt to track safety in the chemical industry.

Self-evaluations by CMA member companies show that

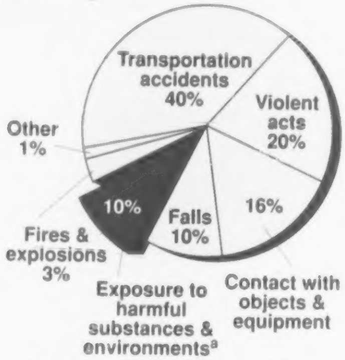
Chemical industry had 34 fatalities in 1992



1992 work fatalities = 34

Source: Census of Fatal Occupational Injuries, Bureau of Labor Statistics

Harmful substances cause few work fatalities



1992 work fatalities = 6,083[b]

[a] Includes electric current (5%); exposure to caustic, noxious, or allergenic substances (2%); and oxygen deficiency (2%). [b] Due to work injuries, all industries.
Source: Census of Fatal Occupational Injuries, Bureau of Labor Statistics

incident investigations, facility design, and safety reviews are the three management practices within the Process Safety Code that have the highest average level of implementation. Lagging farthest behind are the practices relating to sharing safety knowledge and considering public comments and concerns in the design of processes.

But these are averages of averages—and not terribly informative when trying to evaluate how safe the industry is and whether the new rules of the road are making any improvement in chemical process safety.

Injury rates for the chemical and allied products industry appear to be well below the rate for manufacturing as a whole. But those figures, like the data on fatalities collected by OSHA, may be skewed because they do not include contract workers.

Moreover, the number of fatalities in the chemical industry reflected in the OSHA database may also be low because some deaths may not have been reported, and because the database may not have been updated with deaths from cases still classified as open. For example, at the time of this writing, the OSHA data on fatalities presented here do not include deaths from the 1990 Arco Chemical Channelview incident, because the case is not yet closed; and even if they were included, only five of a total of 17 deaths from the incident would appear in this summary for the chemical industry because the other fatalities were contract workers. In short, about all that can be said with certainty is that the figures presented here represent minimum values.

On first glance, injury rates for small to midsized chemical companies seem to be almost double the industry average and nearly three times the rate found in the largest firms, suggesting that smaller companies are perhaps less "safe." But upon further reflection, the significance is unclear. Other factors such as the number of contractors employed, and the number of support, managerial, and other nonplant jobs, may contribute to the difference in rates between small and large firms. The Bureau of Labor Statistics (BLS) is in the process of redesigning its procedures to capture information on occupation type that eventually may help clarify the question.

BLS released its first-ever national census of fatal occupational injuries last month. The census, completed for the year 1992, used multiple sources to identify, verify, and profile fatal work injuries. In contrast to the 23 fatalities in the OSHA database, the BLS census found 34 deaths in the chemical and allied products industry in 1992. Most fatalities were due to transportation accidents and falls. Exposure to harmful substances and environments, and fires and explosions caused the third and fourth largest number of fatalities, respectively.

Injury and fatality rates are only an indirect and somewhat imperfect indica-

OSHA Star: Seal of approval

The Occupational Safety & Health Administration's "good housekeeping seal of approval," the Star certification, has been awarded to 97 sites among 52 companies, of which about 70 sites are chemically related. The Star rating is part of OSHA's Voluntary Protection Program, designed to "recognize and promote effective safety and health management." To be eligible, workplaces must have injury incident and lost-workday injury rates at or below the industry's national average. Companies receiving the Star certification include:

Company	Number of sites
Amoco Foam Products	1
BASF	2
Ciba Chemical	2
Corning	1
Dow Chemical	4
DuPont	3
Exxon	1
GE Plastics	2
Georgia Pacific	2
Hoechst Celanese	2
Huntsman Design	1
IBM	2
Kerr-McGee	4
Lyondell Petrochemical	1
Mobil Chemical	18
Mobil Mining & Minerals	1
Mobil Oil	1
Monsanto Chemical	2
Motorola	2
Ortho Diagnostic Systems	1
OxyChem Petrochemicals	6
Pioneer Chlor Alkali	1
Star Enterprise	1
Texaco	4
Amoco Foam Products	1
BASF	2
U.S. Paint	1
Weyerhaeuser Paper	1

Curriculum development targets safety

One of the newest projects of the Center for Chemical Process Safety (CCPS) of the American Institute of Chemical Engineers is a cooperative effort among universities, industry, and government agencies to develop undergraduate educational materials emphasizing safety, health, and loss prevention.

According to CCPS director Bob G. Perry, some 70 colleges and universities have joined the safety and chemical engineering education program. A set of homework problems has been developed that can be used in undergraduate engineering courses or as class projects. The problems give students an opportunity to apply fundamental engineering principles to such practical examples as storage and handling of hazardous materials, toxicology and industrial hygiene, fire protection, and release mitigation.

CCPS reports that the curriculum materials have been used in nearly one third of the colleges and universities in the U.S. offering chemical engineering training. About 30% of sales of the package have been to industrial organizations.

Perry: emphasizing education

tor of safety in the chemical industry. CMA's proposed Prospect system may offer a more direct measure. According to Donald D. Helin, director of safety, plant operations, and CAER at CMA, the system would require CMA member companies to file annual reports on any fire or explosion causing more than a threshold dollar amount ($10,000 has been proposed) in damage; any reportable chemical release of a substance on CMA's list; and any serious injuries or fatalities. Helin says the data collected under the Prospect system would be establishment-based, so that reports on injuries and fatalities would include all personnel at a site—contract workers as well as employees.

A pilot study of Prospect conducted in several companies helped CMA develop the plan that went before the board last month. Helin says that details on the exact chemicals and thresholds are still being worked out. CMA's goal, he says, is to develop a "meaningful measure that will be credible to the public."

Future prospects

In the longer term, companies seem to be concerned about how to get beyond the safety plateau. "The emphasis at Air Products on prevention of safety problems means that inherent safety is a focus: Safety is designed into the process at the early stages of process development," says Ormsby. "Reducing the inventory of hazardous materials, or even substituting hazardous materials with less hazardous ones—we look at many ways to make the process more inherently safe."

Ormsby says the company also will be giving increasing attention to integrating safety management practices with suppliers and "tollers," or companies that produce materials for Air Products under contract. Ormsby explains that cooperative arrangements relating to hazard analyses and safety reviews are built into the contract, so that Air Products can share its expertise in process safety management and ensure that safety standards are consistent with its own.

Ormsby further points out that a company has to have strong management systems in place that are capable of ensuring that safety standards are met even while weathering changes in business, turnover in leadership, or organizational restructuring.

Bob G. Perry, director of AIChE's Center for Chemical Process Safety, New York City, echoes that theme. "We need better measures of how process safety management is applied on a day-to-day basis and how continuous improvements can be made. Audits are just a snapshot at one point in time. How do we ensure safety standards are met the rest of the time?" he asks.

Perry joined CCPS last March from Union Carbide where he was vice president of manufacturing and engineering. He observes that "there has been a tremendous amount of work to improve the technology needed to improve process safety. Yet the perception may exist that process safety is not improving at the rate people would like it to. Many times, the causes of accidents have less to do with technology and more to do with the failure of management systems to ensure that existing technology and procedures designed to protect safety are efficiently and effectively employed.

"Technology is not enough; you've got to have effective management" to ensure the safety of chemical processes, says Perry. Toward that end, the center has launched a research project aimed at determining how to track and measure the quality of management systems relating to process safety. To begin with, the project is focusing on two elements: management of change, and training. Project personnel will be identifying actual plant sites for closer study.

Another new CCPS initiative is aimed at educating the next generation of chemical engineers in process safety and loss prevention. In the final analysis, eliminating causes of human error and training plant personnel in safe work practices may be a key part of improving safety.

As Mallinckrodt's Boyen concludes, "Safety is not an absolute—it's a relative term. You'll never totally eliminate risk in things—but you do manage risk, and decide what's an appropriate level. You could put in safeguard after safeguard, but still not totally eliminate risk. The reality is, you have to put resources where they're going to do the most good; and you have to train employees to avoid hazards and to work safely." □

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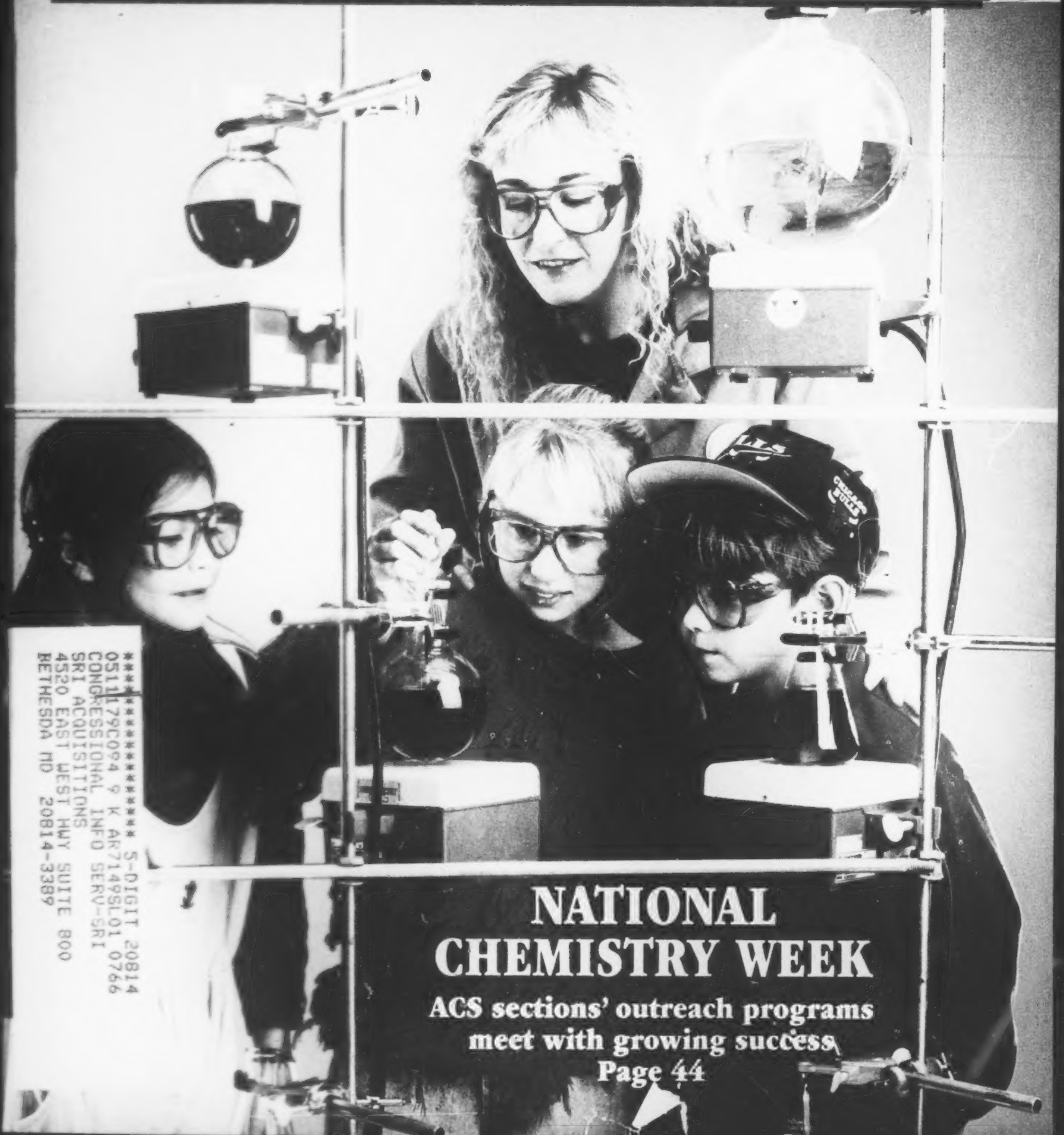
CHEMICAL & ENGINEERING NEWS

C&EN

DECEMBER 6, 1993

STRATEGIES TO IMPLEMENT CHEMICAL ARMS TREATY TAKING SHAPE PAGE 10



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NATIONAL CHEMISTRY WEEK

ACS sections' outreach programs meet with growing success

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C&EN

DECEMBER 6, 1993

NEWS OF THE WEEK

- Federal programs for science, engineering, and technology education lack coordination, evaluation, and accountability, according to an expert panel's report. **Page 6**
- Steadily dropping crude oil prices—and the recent plunge—may bring little benefit to petrochemical producers. **Page 7**
- High-temperature superconducting conductor that carries more than twice the amperage of conventional underground conductors has been produced by American Superconductor. **Page 7**
- Two new zeolites with structures that could permit more highly controlled catalysis are synthesized with organic structure-directing agents. **Page 8**
- Vietnam vets petition the Supreme Court for permission to sue makers of agent orange. **Page 8**
- Genetic engineering techniques, one developed in Italy and another in the U.S., make plants more resistant to disease. **Page 9**

COVER: Students from Lincoln Elementary in Kingsport, Tenn., observe dyes in different solvents as part of Northeast Tennessee Section's National Chemistry Week program. Photo courtesy of Eastman Chemical

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NEWS FOCUS

Executive secretary of the Preparatory Commission, chemical engineer Ian R. Kenyon, discusses strategies for implementing the landmark chemical weapons treaty. **Page 10**

BUSINESS

Pharmaceutical firms are adding internal biotechnology units as avenues for growth in response to changes in health care system and rising competition from smaller firms. **Page 25**

GOVERNMENT

Whether to phase out chlorine and chlorinated organics was debated again by speakers from government, industry, and environmental groups at a meeting in Canada. **Page 31**

SCIENCE/TECHNOLOGY

Planning grants for projects aimed at speeding access to chemical information through electronic technology have been made to eight universities and two colleges. **Page 40**

Mechanism for incorporating carbon monoxide catalytically into organic compounds carbonylates a diacetylene and then adds carbon monoxide. **Page 40**

Japanese chemists asymmetrically synthesize enantiomeric phosphine ligands, chiral at phosphorus, and use them to make asymmetric reaction catalysts. **Page 41**

MEETINGS

PITTCON '94—45th Pittsburgh Conference—miniprogram includes listing of technical sessions together with registration, housing, and other information. **Page 60**

ACS NEWS

The energy and enthusiasm of all 186 local sections made this year's National Chemistry Week the most successful ever. Page 44

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Assistant Managing Editors: James H. Krieger, Janice R. Long, Rebecca L. Rawls, Donald J. Soisson, William J. Storck
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LETTERS

Other effects of EMFs

Your recent news focus on electromagnetic fields by Bette Hileman (C&EN, Nov. 8, page 15) provided extensive coverage on many facets of the controversy regarding health effects of EMFs, but omitted the aspect that is probably of greatest interest to the majority of your readers—effects on chemical reaction rates.

The stimulation of DNA transcription rates, first described by Goodman and Henderson, has been demonstrated in several labs over the past decade, and the resulting changes in protein biosynthesis offer a plausible link to the health effects that were the focus of the article. Other studies have now shown that the changes in protein synthesis caused by electromagnetic fields are similar to the stress response found in all cells, another biologically relevant link to disease. Our own research on changes in the rate of ATP-splitting by the Na,K-ATPase provides another example of an important biochemical reaction that is affected by low-level fields. These and many other studies on the subject appear in the Proceedings of the First World Congress entitled "Electricity and Magnetism in Biology and Medicine," (M. Blank, Editor, San Francisco Press, 1993). For those interested in the latest developments on all aspects of the issue, I strongly recommend that this volume be added to the suggested reading list.

Martin Blank
Department of Physiology
& Cellular Biophysics
College of Physicians & Surgeons of
Columbia University
New York City

I have read with considerable interest the article, "Health Effects of Electromagnetic Fields Remain Unresolved" by Bette Hileman. Unfortunately, neither Hileman nor the individuals she quotes saw fit to present the whole story on biological and health effects of electromagnetic fields. I certainly agree with many of the points in the article, particularly those that indicate that there are bioresponses to certain types of fields and that the hazards remain moot.

The missing part of her presentation concerns the beneficial health effects of selected pulsed electromagnetic fields (PEMFs). Time-varying magnetic fields designed to induce electric fields in tissue similar to those resulting naturally from deformation (for example, strain) during physical activity are used around the world daily to treat various human disease states. PEMFs were approved as safe and effective by the Food & Drug Administration in 1979 for treating chronically unhealed fractures. Since then, upward of 300,000 such cases have been treated with no known risk, no need for surgery, and at a cost of one third to one half of hospitalization for an operation. Healing rates and times are similar to those of bone grafting. The office method is broadly accepted and applied by orthopedic surgeons, more than 17,000 of whom have prescribed PEMFs since FDA's approval.

Many of the biological and cellular effects of PEMFs that are responsible for the healing of ununited fractures have been delineated. In fact, at the biomechanism level, as much is known as for the pharmacologic actions of aspirin. More recently, a variety of other pathologic processes have been proven amenable to control or improvement with selected PEMFs. These include osteonecrosis in young adults (commonly called a "heart attack" of the hip); osteoporosis; osteoarthritis; chronic refractory tendinitis of the shoulder; and brittle bone disease (osteogenesis imperfecta). In each of these, the biological effects of PEMFs appear to address specific features of the underlying pathology.

Cardiac and cerebral ischemia (that is, heart attack and stroke) also have been reported in the past two years to benefit from early use of PEMFs in animal studies. Although the biomechanisms of action in these two conditions are not yet defined, possible effects on nitric oxide and oxygen radicals (for example, via superoxide dismutase) seem to be prime targets for study.

During the course of basic science studies on PEMFs, a number of biological and physical principles have emerged on specificity. These indicate that lumping time-varying magnetic fields into a common pattern of bioeffects is not only incorrect, but stunts progress toward a broader understanding of both potential hazards and new benefits. In the biohazard arena, epidemiologic and laboratory studies that assume that 50- or 60-Hz sine fields are the "culprit" may be far off base, if data from the benefit arena have any validity. Until spectral analysis of line voltage alterations by power surges, switching transients, and a host of other sources of field pattern modifications are incorporated into "hazard" research, the complexities of biosignaling probably will continue to wallow in a sea of confounders.

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SCIENCE EDUCATION

Federal programs lack coordination

Federally funded education programs in science, mathematics, engineering, and technology are "burdened by a lack of coordination, a lack of evaluation, and a lack of accountability," says a report released last week by a panel of experts.

The federal investment in science education needs a stronger management plan to provide balance and coherence across federal agencies, the panel concludes. Existing programs need to be evaluated consistently and rigorously, then modified, dropped, or expanded in light of the results of the evaluations.

The 15-member Expert Panel for the Review of Federal Education Programs in Science, Mathematics, Engineering & Technology was appointed in January 1993 by the education committee of the Federal Coordinating Council for Science, Engineering & Technology (FCCSET). The National Science Foundation (NSF), one of the 16 federal agencies making up FCCSET, directed and supported the panel's work.

The panel identified nearly 300 education programs budgeted at almost \$2.2 billion for fiscal 1993. It did not study each program exhaustively, but looked at the scope of the federal effort as a whole, and the extent to which it has been evaluated. "This is the first time federal programs have been examined as a whole under independent scrutiny," says panel cochairman Karl S. Pister, chancellor of the University of California, Santa Cruz.

"Much of the reform called for 10 years ago in the National Commission on Excellence in Education's landmark report, 'A Nation at Risk,' remains unfinished," Pister notes. "The federal effort is not sufficiently coordinated to reverse the mediocrity that exists. The programs need to be managed as a portfolio of investments." That will require a new culture of interaction among and within federal agencies, he adds.

Panel cochairman Mary Budd Rowe, professor of science education at Stanford University, points out that only one in five programs has been evaluated. One of the panel's key recommendations is that programs be evaluated rigorously to judge how effective they are in meeting identified goals. "We can't afford to be investing big amounts in programs that don't work," she stresses. "We need to be supporting those that do."

1993 budget targeted $2.2 billion for science education

$ Millions	Total	K–12	Undergraduate	Graduate	Public understanding of science
NSF	$ 537.9	$309.8	$143.1	$ 79.1	$ 5.9
Defense	526.7	24.8	140.1	361.8	0
Health & Human Services	464.1	26.9	33.4	401.9	1.9
Education	340.9	328.3	12.6	0	0
Energy	102.1	27.4	52.1	17.5	5.1
Interior	86.0	23.1	7.9	10.8	44.2
NASA	79.8	20.5	24.8	34.5	0
Agriculture	24.4	1.2	13.7	9.5	0
Smithsonian	10.1	0.7	0.1	0.5	8.8
EPA	9.0	7.1	0.9	1.0	0
Commerce	5.2	0	0	5.2	0
TOTAL	**\$2,186.2**	**\$769.8**	**\$428.7**	**\$921.8**	**\$65.9**

Source: "The Federal Investment in Science, Mathematics, Engineering, and Technology Education: Where Now? What Next? Sourcebook," August 1993, National Science Foundation.

C&EN staff photo

Williams: sustained evaluation needed

Luther S. Williams, NSF's assistant director for education and human resources and acting chairman of the FCCSET education committee, acknowledges that there has not been a sustained, comprehensive evaluation effort among federal agencies. "We have a backlog, a cumulative debt for not having done it in the past," he says.

Even before the expert panel completed its report, FCCSET's education committee developed a comprehensive plan that sets a five-year schedule for evaluating all the federal programs, Williams notes. The new report validates that plan and will be valuable in getting Congress and agencies to commit the necessary resources, he adds. Currently only about 1% of the total science, mathematics, engineering, and technology education budget is set aside for evaluation; Rowe estimates that about 10% ought to be.

The panel makes three other major recommendations. It advises investing in learning what works. "The federal government is in a unique position to provide leadership in educational research to determine what works in particular educational settings," Rowe says.

The federal government also should market its investments, according to the panel. "All of us on the committee discovered all sorts of programs that we simply didn't know about," Rowe notes. "People aren't finding out about the good stuff that's going on."

The panel also recommends investing in the future by providing aid for teacher training at all education levels. "In the view of the panel, some of the worst teaching going on is at the university level," Rowe says. She points out that chemistry courses have the highest dropout rate of all college-level courses.

Pamela Zurer

Oil price drop may not benefit petrochemicals

After slipping steadily over the past summer, crude oil prices plunged more than $1.00 per barrel early last week—falling to $15.30 a barrel for January delivery of West Texas intermediate crude, for example, the lowest level in five years. The world oil market was moving aggressively to punish the Organization of Petroleum Exporting Countries for refusing to cut production.

Ironically, this drop in oil prices may bring little benefit to petrochemical producers, even though crude oil is a key raw material for making a spectrum of basic olefins and aromatic chemicals: makers of plastics and other downstream goods are demanding discounts on petrochemicals almost as quickly as petrochemical producers cut their own costs because of lower feedstock prices.

"The precipitous drop in crude prices last week has really made the petrochemical users more conscious of a trend that has been happening for many months," notes Dexter Miller, a vice president at DeWitt & Co., a Houston-based consulting firm.

"If petrochemical producers could get a ride out of this [crude oil price drop], it would really help them right now. But they won't," adds Michael Horvath, senior consultant at Bonner & Moore Associates Inc., a consulting firm also based in Houston. Depending on the petrochemical, producers may enjoy only between a week to two months of improved profitability because of lower feedstock prices, Horvath tells C&EN.

Fluctuating feedstock costs are a big headache for petrochemical producers. When crude oil prices rise, petrochemical companies usually find it hard to raise prices of basic petrochemicals in proportion. The companies typically must give customers a month's notice of a price increase, and it often does not fly anyway, points out a source at a major chemical company.

However, the customers who resist price increases when feedstock prices rise usually are the same ones who demand immediate discounting off contract list prices when feedstock prices drop. "So the most profitable scenario is one with stable raw material prices," the source stresses.

Michael R. Krenek, vice president for chemicals at the Houston-based chemical consulting firm of Wright Killen & Co., notes, "When crude prices fell dramatically in 1986, petrochemical prices did not experience the same proportional decline that one would have expected. Critical variables were not conducive to such a phenomenon. For example, supply and demand were relatively balanced, demand for plastics was growing at a rapid rate, and exports were at high levels."

However, Krenek continues, now "these positive variables do not exist. In today's competitive environment it is more likely that decreases in feedstock costs will benefit consumers rather than petrochemical producers, as these reductions are reflected in lower end-product prices rather than in increased margins" for petrochemical producers.

U.S. makers of ethylene—a major petrochemical building block—may be hit particularly hard by the drop in crude oil prices. Seventy-five percent of all ethylene produced in the U.S. is based on natural gas liquids such as ethane, propane, or butane (only 25% is made from crude-oil-derived gas oil or naphtha). But end users of ethylene "are asking for price discounts in total disregard to what ethylene producers are using for feedstock," says Horvath.

While natural gas liquids prices are dropping "in sympathy" with crude oil prices, as is typical in energy markets, natural gas prices are not dropping as fast as crude prices, Horvath adds. Thus, profit margins at companies that make ethylene from natural gas liquids will drop faster than profits at firms that crack gas oil or naphtha.

Susan Ainsworth

Superconducting cable achieves high current

American Superconductor (ASC), Westborough, Mass., has produced a prototype, high-temperature superconducting conductor that exceeds the current-carrying threshhold required for commercial underground power transmission cables. ASC's partner in the project is Pirelli Cable of Milan, Italy.

The 1-meter-long conductor—based on a bismuth-strontium-calcium-copper oxide (BSCCO) superconductor (T_c = 110 K)—carries more than 2,300 amps of direct current at liquid nitrogen temperature (77 K), more than twice the typical 1,100 amps carried by conventional underground copper conductors. The Electric Power Research Institute, an industry-based R&D consortium that has funded development work at Pirelli, estimates that a current of 2,000 amps is desirable for cost-effective use of high-temperature superconducting cables in power transmission.

The ASC/Pirelli conductor competes with ones being developed by a Japanese company, Sumitomo Electric Industries, and by Intermagnetics General of Guiderland, N.Y. Gregory J. Yurek, ASC's president and chief executive officer, says that his firm now is "neck and neck" with Sumitomo, which is working with Tokyo utilities. "It's clearly been shown that the electrical performance of high-temperature superconductors is up to the task of achieving commercial needs," he says.

However, Carl H. Rosner, president of Intermagnetics—which develops high-temperature superconducting materials for use in power generation equipment as well as transmission cables—believes there will be greater market potential for superconducting cables that carry alternating, rather than direct, current.

ASC, founded in 1987, produces the superconducting wires used to make larger multistranded conductors by a widely used process called oxide powder-in-tube. In simple terms, a silver tube is packed with powdered precursor materials, drawn out into a wire,

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Editor: Michael Heylin (202) 872-4501
Managing Editor: Madeleine Jacobs
Assistant Managing Editors: James H. Krieger, Janice R. Long, Rebecca L. Rawls, Donald J. Soisson, William J. Storck
Staff Editor: Ernest L. Carpenter
Senior Correspondents: Earl V. Anderson, Lois R. Ember, Wilbert C. Lepkowski
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News Bureaus: Northeast: (908) 906-8300 Ann M. Thayer (Head), Rachel Eskenazi (Administrative Assistant). Houston: (713) 558-2912 Susan J. Ainsworth (Head). Washington: (202) 872-4495 David J. Hanson (Head). West Coast: (510) 653-3630 Rudy M. Baum (Head), (206) 517-5034 Deborah L. Illman (Associate Editor) **Foreign Bureau:** London: (01) 4481 870-6884 Patricia Layman (Senior Editor)
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LETTERS

CHEMICAL SAFETY

Azide explosions discussed

There is every reason to suppose that eschewing halogenated solvents will not eliminate azide explosions such as those reported by N. P. Peat and P. M. Weintraub (C&EN, April 19, page 4) and by Victor J. Hruby, Lakmal Boteju, and Guigen Li (C&EN, Oct. 11, page 2). The first group explicitly combined sodium azide and sulfuric acid, generating hydrogen azide, which is very explosive. The second group's report was less explicit, but the cold traps of the vacuum pump of the rotary evaporator were involved, implying an explosive more volatile than dichloromethane.

Hydrogen azide (boiling point 37 °C) fits this description. The boiling point of diazidomethane may be known, but not to me; I should expect it to be at least 90 °C. This means explosions late in solvent stripping, either in the evaporating flask or in the condenser. On the evidence offered your readers, there is no reason to postulate the complicated reaction leading to diazidomethane, even though it can occur in other circumstances.

Hydrogen azide is also, of course, extremely toxic, and it is a rare explosion that consumes all the explosive, rather than spraying it around.

Peter G. Urben
Editor, "Bretherick's Handbook of Reactive Chemical Hazards"
Kenilworth, Warwickshire, England

Ball mill reactor

The article "Novel Idea Developed To Destroy Toxic Chemicals," by Stu Borman, was very interesting (C&EN, Oct. 11, page 5). The mechanochemical technique, or ball milling technology, to carry out stubborn chemical reactions is unique but scarcely novel. I was highly pleased to note that others have also recognized the potential application of the lowly ball mill for this purpose.

Back in 1958–59, while working in the R&D division of Ethyl Corp. in Baton Rouge, La., I discovered that a ball mill was a very effective reactor to make difficult reactions go to completion with high yields. This was demonstrated by combinations of solid-solid, solid-gas, and liquid-gas reactants. Our ball mill design was unique. It could be heated or cooled and was designed with hollow trunions with pressure seals to safely feed and discharge reactants and products that were either hazardous or sensitive to air or moisture exposure.

Our ball mill design was furnished to a ball mill manufacturer, who advertised it as a "mill reactor." Details of the research and development of the ball mill reactor were later described in a technical paper [*I&EC Product Research & Development*, **2**(3), 238 (1963)]. Copies of this paper, "Preparation of Sodium Alpha-Sodioalkanoates by the Reaction of Sodium Alkanoates with Sodium Metal," have been widely distributed.

George W. Mattson
Emeritus member
Santee, Calif.

The idea of ball milling toxic chemicals is one of those "Now, why didn't I think of that" things. I don't see any reason to doubt that the Aussies have accomplished what they say they have, even if they haven't told all. It opens up the possibility that other mechanical devices could be used, for example, crushers, grinders, milling machines, rollers, and stamp mills; although the ball mill certainly has the advantage of simplicity and complete con-

Notice to members wishing to resign

ACS members who wish to resign their membership at the end of 1993 should do so now by letter to the ACS executive director. Bylaws specify that anyone who fails to resign by Dec. 31 will be carried on the rolls in 1994 as a member and will be responsible for dues. Failure to pay dues does not constitute a resignation.

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to convert defense technologies to civilian applications. The idea is to cut federal red tape from government purchases of new technology from industry. The current process is cumbersome and expensive and discourages companies from wanting to develop innovative technologies. The council is likely also to rate that process in its next scorecard.

Another category Fisher mentions is the government's role in remaking the country's technological infrastructure—from bridges and roads to information systems. With regard to what role the technology community can play in improving the country's social infrastructural problems—bad schools, broken families, children lost to crime—Fisher says the problems are tough but important. Focusing mainly on the impact of the information revolution on society, Fisher says he is worried that the poor will be left out.

Wil Lepkowski

Civilian spending up in 1994 R&D budget

Putting the final touches on the fiscal 1994 federal budget was one of the last items of business Congress completed before adjouring for the year. Overall research fared quite well, particularly civilian sector research.

According to the Office of Management & Budget, Congress approved 82% of the new research investments sought by President Clinton as part of his economic revitalization plan. In line with that plan Congress provided increased resources for information highways, energy research, National Aeronautics & Space Administration (NASA) research and development, National Science Foundation (NSF) research, National Oceanic & Atmospheric Administration (NOAA) weather technology, National Institute of Standards & Technology (NIST) programs, and multiagency research programs organized by the Federal Coordinating Council on Science, Engineering & Technology.

The last two fiscal 1994 appropriations bills to be signed into law provided research funding totaling $36 billion for the Department of Defense and Department of Interior, plus parts of the Agriculture and Energy departments. Adding that figure to research funds previously appropriated (C&EN, Oct. 25, page 20) brings total research funding for fiscal 1994 to $65 billion, 2% less than what was spent in 1993 and 5% less than the Administration wanted.

All of the decline can be accounted for by the 8% fall to $36 billion in funding for DOD and DOE defense research programs. Funding for civilian R&D is actually up 7% to $29 billion, almost exactly what the Administration requested.

The decline in DOD's research funding didn't lead to a concomitant decline in earmarks for specific projects. According to Rep. George E. Brown Jr. (D.-Calif.), while "a complete analysis of the Defense appropriation bill [H.R. 3116] will take weeks of work, a quick analysis indicates that there are probably several billion dollars in earmarks folded into the bill and accompanying reports." In a few short hours, his staff found apparent set-asides accounting for 3% of the Air Force's total research budget, 6% of the Army's, 5% of the Navy's, and 9% of the research budget for the defense agencies.

Brown admits that not all of these may be earmarks in the accepted sense of the word. They certainly are, however, "items of special Congressional interest." Essentially, Brown says this "means that any desire by DOD or the services to spend those monies in any other way or to spend less than the designated amount requires the prior approval of the appropriators."

In the Senate, Sen. John McCain (R.-Ariz.), who believes that earmarks are seriously harming military effectiveness, warned that if next year he does not have enough time to find and try to delete earmarks from the appropriation, he will object to consideration of the conference report. That could stall the bill's passage for some time.

No sooner had Congress settled the fiscal 1994 research budget, earmarks and all, than the House, prompted by the Administration, started whittling it down. In its reinventing government proposals (C&EN, Oct. 11, page 20) the Administration proposed cutting some $2 billion from the 1994 federal budget, including the research budget.

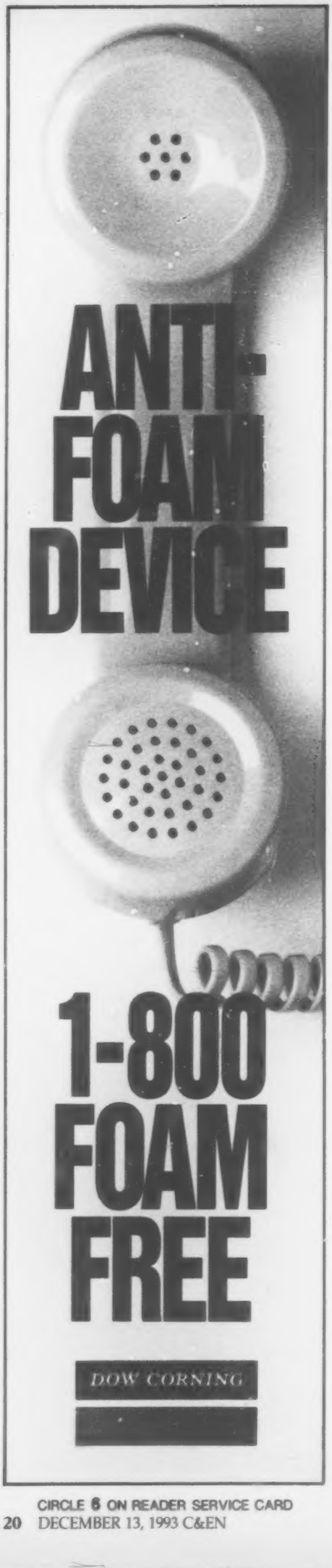
For example, it proposed cutting $25 million from the Agricultural Research Service's $725 million budget and $64 million from the Cooperative State Research Service's $511 million budget. The House rejected the ARS cut and limited the CSRS cut to $14 million. It went along with the proposed total cut of $97.3 million from the Department of Energy's $4 billion energy supply R&D account and made some cuts that the Administration hadn't sought. These include $25 million from NASA's $2 billion R&D account and $10 million from the $100 million provided for NSF's academic research infrastructure revitalization program.

Things could have been worse. Before approving the Administration's reinventing government plan, H.R. 3400, the House rejected an amendment put forward by Rep. John R. Kasich (R.-Ohio) and Rep. Timothy J. Penny (D./Farmer/Labor-Minn.) that not only would have cut substantially more from the 1994 research budget, but would have totally reorganized the federal research establishment.

Congress cuts '94 defense research funds 8%

	1994			% difference	% change
$ Millions	Appropriation	Request	1993	Appropriation/ request	1993–94
DOD R&D	$34,947	$38,336	$37,962	–9%	–8%
Air Force	12,314	13,695	13,199	–10	–7
Defense agencies	8,839	10,175	9,800	–13	–10
Navy	8,366	9,216	8,930	–9	–6
Army	5,428	5,250	6,033	3	–10
Energy	828	818	723	1	14
Fossil R&D	431	398	418	8	3
Conservation R&D	397	420	305	–6	30
USDA forest research	193	194	183	–1	6
Interior—National Biological Survey research	83	83	87	–1	–4
TOTAL	$36,051	$39,431	$38,955	–9%	–8%

Source: Congressional reports on fiscal 1994 appropriation bills



CIRCLE 6 ON READER SERVICE CARD

Their amendment called for creation of a new Department of Science, Space, Energy & Technology encompassing DOE, NASA, NIST, NOAA, NSF, the National Technical Information Service, the Patent & Trademark Office, the Office of Science & Technology Policy, and the technology programs of the Department of Commerce. In addition, the amendment called for cutting $220 million in 1994 from federal academic R&D programs sponsored by DOD, NIH, and NSF and for sharp cuts in DOE's fossil and fusion research accounts, plus termination of the clean-coal technology program.

The Senate won't take up the reinventing government package until after Congress reconvenes in late January, and there's no guarantee that a proposal similar to the one by Penny-Kasich won't surface then.

Money wasn't the only item on the agenda as Congress closed down its first session amid a flurry of activity, but not many items made it through both branches of Congress. One bill that did was H.R. 3216, introduced Oct. 5, which closes a loophole in the Chemical Diversion Control Act.

Currently, manufacturers of over-the-counter drugs approved for sale by the Food & Drug Administration do not have to report sales to the Drug Enforcement Administration (DEA). However, clandestine laboratory operators have been obtaining large quantities of 25-mg ephedrine tablets for use in making two powerful stimulants, methamphetamine and methcathinone. The latter is posing a particular problem in Michigan's Upper Peninsula, according to the bill's sponsor, Rep. Bart Stupak (D.-Mich.), who represents the area. The bill removes the exemption for ephedrine, requiring record keeping and reporting of sales of drugs in which it is the only active ingredient. The bill also grants DEA the authority to remove the exemption from any other chemicals used in the illicit production of controlled substances.

The House approved legislation, H.R. 1994, providing the first formal authorization for Environmental Protection Agency research programs since 1982. The bill would require EPA to set up a fundamental program in support of ecological, health, and risk-reduction research; establish a program for modernizing and upgrading its research facilities and equipment; and focus its research program on the 10 environmental hazards that pose the greatest risk to human health and the environment. The House also approved H.R. 3512, a bill that would abolish the Council on Environmental Quality and replace it with a White House Office of National Environmental Policy Act Compliance. The Senate will be taking up both issues next year.

Janice Long

Defense Department to accept unwanted halons

Afraid that some owners of halons will vent the ozone-depleting chemicals to the atmosphere rather than pay a stiff new tax that soon goes into effect, the Department of Defense has cut through red tape and is offering to immediately accept unwanted material. A private firm, BP Exploration Alaska, is making a similar offer.

Production and import of halons—brominated fluorocarbons used to fight fires—will be banned as of Jan. 1 under the Montreal Protocol on Substances That Deplete the Ozone Layer and the U.S. Clean Air Act. In actuality, demand has dropped; no one has been making the chemicals for months. The current supply, most of which is "banked" in existing fire-suppression systems, is expected to last for decades now that unnecessary emissions such as those from discharge testing have been curtailed.

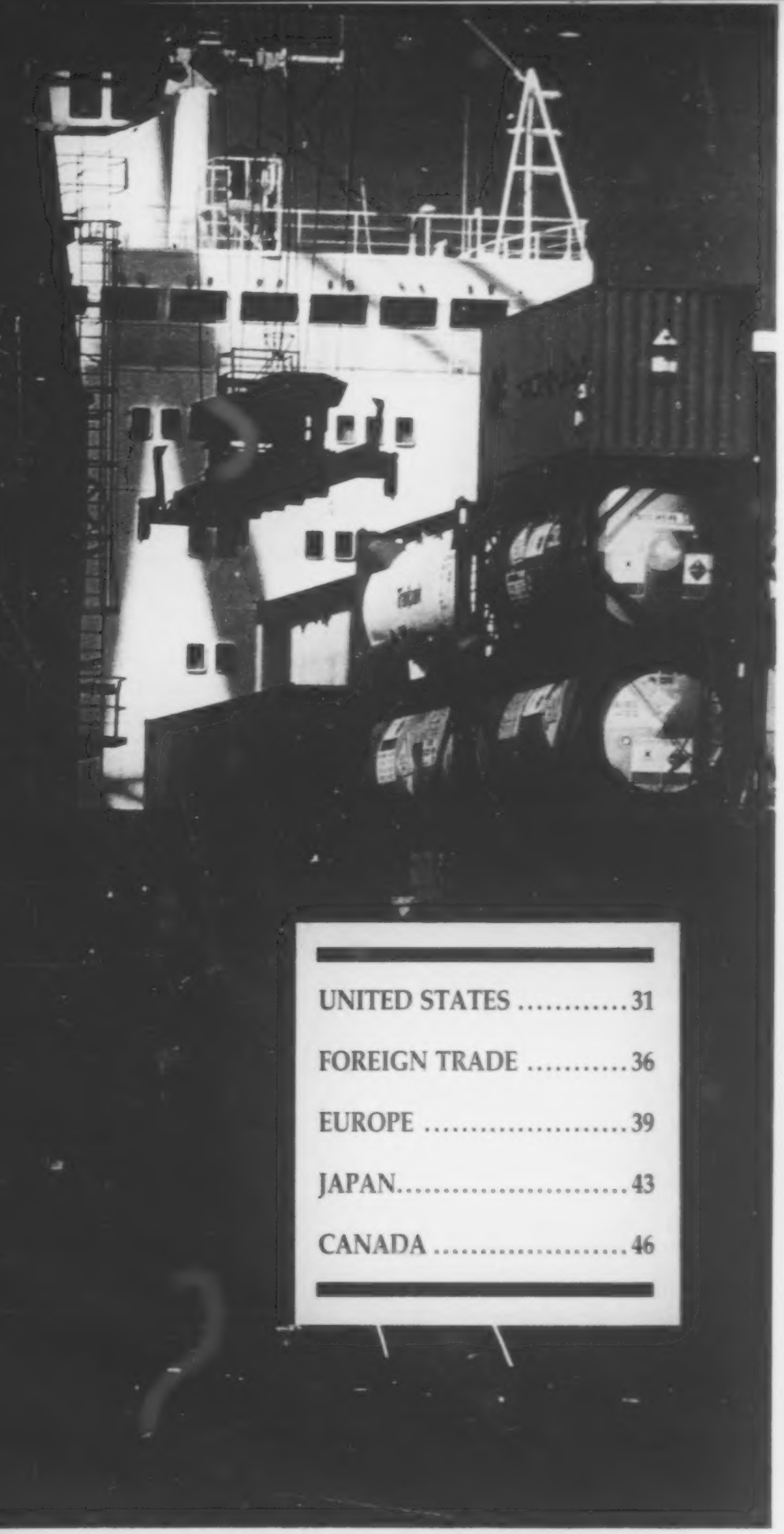
Also on Jan. 1, manufacturers and distributors of pure halons will be subject to a tax of $43.50 per lb on their unsold inventories. (Halons currently cost about $6.00 or $7.00 per lb.) The tax applies only to halon owners holding the chemicals for sale on that date, not to end users who have halons in their equipment. Used and recycled halons are not subject to the tax.

Some environmental organizations have been concerned that halon owners might release the chemicals into the air rather than get stuck with the tax. Many such owners are small "mom-and-pop" distributor operations that maintain and refill extinguishers for local businesses.

"We've heard estimates that there are 500,000 to 1 million lb of halons sitting in storage at distributors," says Dave Kolar, president of Navesink Environmental Testing in Red Bank, N.J., and chairman of the Sierra Club's ozone depletion working group. "Small businesses are facing a tax that could potentially bankrupt them versus venting, which they may not get caught at."

PACECO PORTAINER

WORLD CHEMICAL



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OUTLOOK

As 1993 draws to a close, it is apparent that the world chemical industry has a long way to go to get back to the health it enjoyed in the late 1980s.

If the world's countries were in a hospital, they would be in a variety of conditions. The U.S. and Canada would be in the recovery room, perhaps in guarded condition. However, most of Europe would be in serious condition and Japan would be in intensive care.

The U.S. chemical industry, having cut costs over the past couple of years, is showing signs of improvement, not only in demand, but also in terms of financial health. Its recovery so far is fragile, but if general economic trends that have appeared in the second half of this year continue, the industry likely will be in decent shape by mid-1994.

The one continuing problem in the U.S. is trade. Weak economies elsewhere in the world have slowed exports from the U.S. and have shrunk the traditional U.S. chemical trade surplus. But, predictions are for export growth next year, and this, along with increased domestic demand, likely will provide higher operating rates and profits for the U.S. chemical industry.

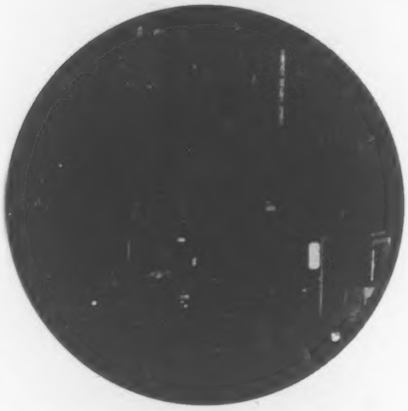
Canada, after some severe bloodletting in terms of employees and plants, is following closely behind the U.S. in recovery, and, helped next year by improving exports, probably will be well on the mend.

In Europe, however, the chemical industry is being hurt considerably by industry overcapacity and high social costs. Plans are evolving to cut capacity, especially in petrochemicals, and the high overheads may be reduced in some countries such as Italy, as it privatizes its chemical industry. But most European chemical companies still see little hope in 1994.

The chemical industry in Japan is taking drastic measures for that country to prevent the already bad state of chemicals from getting worse.

And all over the world, chemical companies continue to realign their product portfolios, shucking off businesses that don't fit into their plans, buying businesses that they believe will fit well with existing operations, and getting rid of the fat in hopes of finding robust health once again.

UNITED STATES



Chemical Industry Lackluster This Year

1994, however, looks to be much better in earnings and profit margins if upturn continues to build

William J. Storck,
C&EN Northeast News Bureau

Prospects for the U.S. chemical industry are looking up. After continuing declines in industry fundamentals through 1992 and into the first part of 1993, chemicals are beginning to perform better. And the outlook for 1994 seems to be more of the same.

Although about the best that could be said for this year is that it will be better than 1992 in terms of sales, profits, and profitability, it may well mark the turning point for many chemical companies from the long slide of the past few years.

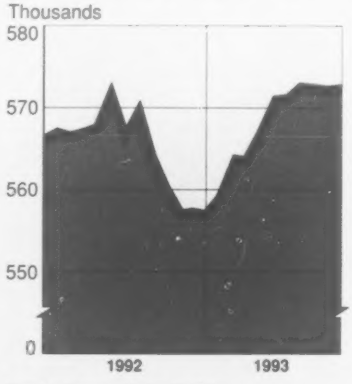
The reason for the optimism is not so much that all of 1993 has been good, but that there has been a pickup in the past few months in major downstream markets such as automobiles and housing. Also, the U.S. chemical industry has spent the past couple of years cutting costs in terms of employment and processes. The result, in spite of struggling economies in other parts of the world, should be continued expansion next year.

This year started out the same as the past few. During the first quarter, as a group the 30 major chemical companies regularly surveyed by C&EN continued to post lower year-to-year earnings, as they had for the previous 14 quarters. However, by the second quarter, many of these same chemical companies were posting earnings increases big enough to produce the first annual growth in total quarterly earnings of this group since the second quarter of 1989.

Thus, 1993 probably will show an increase over 1992 in earnings from continuing operations, excluding extraordinary and nonrecurring items—probably the best measure of industry health.

This year has really not been all that bad for growth in the chemical industry. During the first nine months of 1993, shipments of chemicals and allied products totaled about $237 billion, according to the Commerce Department, an increase of 4.1% over the same period in 1992. And shipments of industrial chemicals during the same period rose 3.4% to $122 billion.

Number of chemical production workers rises



Source: Bureau of Labor Statistics

The Society of the Plastics Industry reports that for the first three quarters, total resin shipments increased 4.1% to almost 46.3 billion lb and during September, resin shipments were up more than 9% to 5.3 billion lb.

Synthetic fiber shipments have not performed as well as plastics, however, but through the first nine months, shipments of noncellulosic fibers increased 2.4% to 6.6 billion lb.

The increase in chemical shipments this year has been supported by a rise in production. The average industrial production index for chemicals and allied products through the first nine months was 118.0 (1987 = 100), 3.2% higher than for the same period last year.

The laggard in the economic picture has been chemical prices, which during the first nine months of this year were up just 2.2% over the same period of 1992 to an average producer price index of 128.2 (1982 = 100).

Thus, the outlook for the remainder of this year is pretty good, enabling the chemical industry to finish 1993 with a better record than it achieved in 1992. U.S. chemical shipments for the year will probably fall somewhere between $312 billion and $314 billion, with the high side looking fairly probable. Shipments of industrial chemicals, which totaled $156 billion in 1992, likely will amount to almost $162 billion for this year.

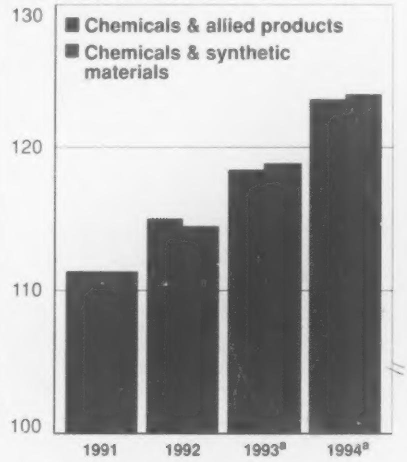
Production also will maintain its growth for the remainder of the year, with chemicals and allied products finishing at an average index of 118.4, up from 115.0 in 1992. And output of industrial organics, inorganics, and synthetic materials will grow from a 1992 index of 115.5 to an index of 118.9 this year.

But the price index for chemicals and allied products will probably finish the year with no better growth than 2%, while that for industrial chemicals will be up an even lower 1.1%.

In terms of the general economy, the outlook for the fourth quarter of this year and into next seems to be brighter. Economists have been speaking once again of "pentup demand" for high-end products such as automobiles and housing, and

Chemical production will continue to rise . . .

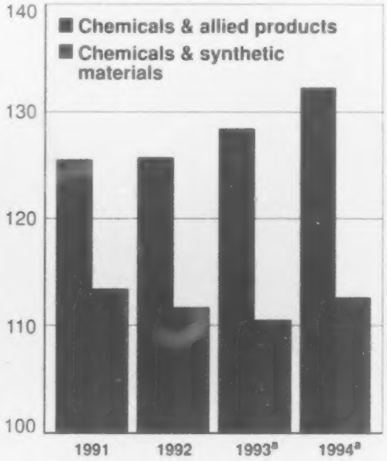
Industrial production index, 1987 = 100



a C&EN estimates. **Source:** Federal Reserve Board

. . . and prices will rise some in 1994 . . .

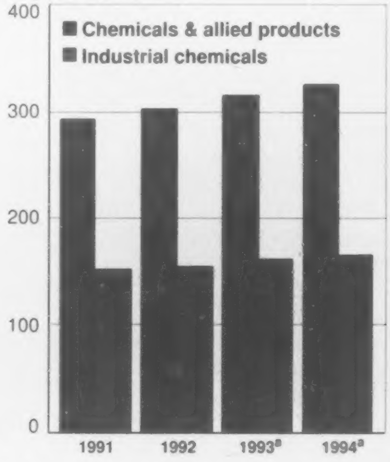
Producer price index, 1982 = 100



a C&EN estimates. **Source:** Bureau of Labor Statistics

. . . as demand increases moderately

Shipments, $ billions



a C&EN estimates. **Source:** Bureau of the Census

they believe that consumers, spurred by low interest rates, are beginning to buy these items. Pentup demand is economic jargon for what people want to buy during a recession, but can't afford.

Two of these downstream markets—automobiles and housing, which use large quantities of chemical products—seem to be poised for a decided upturn as consumers turn loose their cash.

Housing, which has been in the doldrums for a few years, especially seems to be on the verge of sustained improvement, brought on by the combination of pentup demand and low interest rates. New home sales in September and October combined showed a healthy 10% rise from the same two months in 1992.

In plastics, new housing construction seems to be having an effect on the normally lackluster sales of thermosetting resins, many of which are used in construction materials. For instance, while total sales and captive use for all plastic resins were up 4.1% for the first three quarters of 1993, thermosetting resins grew 8.5%. And in September, in spite of a much improved 9.1% growth for all resins, thermosets still led the way with an 11% increase. Sales of melamine resins, some of which go to the construction industry, registered a phenomenal 75% gain for the first three quarters; however, this is on small volume. The much larger volume urea resins are more typical, with a 13% increase in the first nine months.

Fibers also show the effects of new construction (where the builder usually installs carpet) and sales of existing homes (where purchasers often replace carpet after they buy). While total synthetic fiber shipments increased 2.4% in the first nine months, shipments of yarn and monofilament rose 4.0%. And almost all of this growth was provided by carpet nylon, up 8.1% from the same period in 1992.

In another major chemical market, fertilizers are also expected to get a boost in demand in 1994, as farmers increase acreage planted to make up for crops lost in the 1993 flooding in the Midwest. However, fertilizer producers also must contend with extremely low pricing. The Department of Agriculture predicts that supply and demand will be in balance next year, so whether fertilizer producers can improve their lot by raising prices remains to be seen.

Despite the headlines about declining chemical employment, the outlook for 1994 is good for production workers. Although employment has declined and will continue to do so as companies restructure their operations, most of the cuts have come in the white-collar segment of management, sales, and support. The numbers of chemical production workers actually are increasing and have been since early in 1993. Total production workers for chemicals and allied products had declined from 606,000 at the end of 1989 to 557,000 by January of this year, but by November 1993 chemical producers had added 15,700 more.

And this growth in production workers comes while the chemical workweek for most of the year has remained above a very healthy 43 hours, indicating that, barring some dramatic downturn, which economists are not predicting, chemical production will continue to grow well into 1994.

Oddly, much of the increase in production workers has come in the highly cyclical industrial chemicals and synthetics segments. Producers in these areas added 9,000 workers between January and October (November 1993 data are not yet available for this group) and added 13,500 since the 1992–93 low of 231,800 production workers in December last year.

This carryover of these good industry fundamentals bodes well for the fortunes of the chemical industry next year, although most analysts seem to be wary in their predictions. For instance, a survey by the Chemical Manufacturers Association of its members indicates a growth in sales next year of about 5% and growth in income of about 10%.

This forecast is probably about as good as any, although the earnings prediction may well be on the slightly conservative side. Chemical producers have lowered their costs and thus their break-even points so that each 1% increase in sales probably will garner more than a 2% increase in earnings. ☐

FOREIGN TRADE

U.S. Chemical Trade Surplus Declines

Surplus will shrink to $15.7 billion as weak economies overseas keep export growth low; rebound forecast for 1994

Earl V. Anderson,
C&EN Northeast News Bureau

In the past two years, the economies of the world's major industrialized nations have flip-flopped. The result hasn't helped U.S. chemical trade performance. The chemical industry's prized trade surplus—the excess of chemical exports over imports—has slipped for the second year in a row.

In 1991, the U.S. was mired in recession while the economies of other industrialized countries were holding up fairly well by comparison. With a lid on domestic markets and more capacity available to produce for foreign markets, U.S. chemical companies pushed their exports ahead by more than 10%. And with low demand in the U.S., chemical imports advanced only 7.6%, and the U.S. chemical trade surplus leaped to a record $18.8 billion.

Since then, the U.S. economy has been recovering, albeit slowly. Meanwhile, the economies of other industrialized nations, particularly Japan and European countries, became bogged in recession.

This reversal has taken its toll on U.S. chemical trade. Faced with stagnant markets in many countries, U.S. chemical exports advanced only 2.3% last year and probably will grow only 2.1% this year to $44.9 billion. That's a new record.

Chemical imports, however, are growing faster. They increased 14.5% last year and likely will advance 5.5% this year—more than twice as fast as exports. That will push the 1993 chemical import total up to $29.2 billion, also a new record.

The increase in chemical imports will also lower the U.S. chemical trade surplus to $15.7 billion, from $16.3 billion in 1992. That's the lowest it's been since 1989.

A recent survey by the Chemical Manufacturers Association (CMA) indicates that its member companies expect chemical exports to bounce back next year with a 5% growth. However, CMA members expect little change in imports next year. The consensus: an increase of only 1%.

If those survey results are right, U.S. chemical exports in 1994 will reach a record $47.1 billion, while imports inch up to $29.5 billion. That would reverse the two-year slump in the chemical trade balance and push it back up to $17.7 billion, second only to the record $18.8 billion in 1991.

Those survey results may turn out to be overly optimistic. According to CMA, its large-company members—those with sales of more than $1 billion—think that next year's chemical exports will increase only 2.8%, not the consensus 5%. CMA notes that for this year, its members also predicted that exports would increase 5%, instead of the 2.1% actual figure.

All U.S. chemical exports except fertilizers are up this year

	U.S. chemical exports				U.S. chemical imports			
$ Millions	1993[a]	1992	1991	1990	1993[a]	1992	1991	1990
Organic chemicals	$11,045	$10,993	$10,928	$10,400	$ 9,344	$ 9,366	$ 8,157	$ 7,392
Plastics in primary form	7,319	7,178	7,537	6,428	2,716	2,247	1,930	1,974
Medicinals & pharmaceuticals	5,747	5,357	4,606	4,103	4,146	3,812	3,053	2,500
Inorganic chemicals	4,131	4,119	4,102	3,816	3,241	3,300	3,299	3,234
Plastics in nonprimary form	3,278	3,076	2,786	2,633	2,132	2,046	1,855	1,774
Essential oils, perfumes, toilet & cleansing preparations	2,963	2,631	2,361	1,963	1,752	1,711	1,417	1,323
Dyeing, tanning & coloring materials	1,976	1,867	1,648	1,588	1,723	1,681	1,416	1,288
Fertilizers	1,751	2,372	2,980	2,574	1,168	952	919	955
Other	6,690	6,363	6,019	5,478	2,978	2,569	2,123	2,028
TOTAL	**$44,900**	**$43,956**	**$42,967**	**$38,983**	**$29,200**	**$27,684**	**$24,169**	**$22,468**

a C&EN estimates **Source:** Bureau of the Census

CMA also says that companies represented in the survey aren't "accurate predictors" of import growth. Unless some of the major overseas economies start a solid recovery, it's reasonable to expect that chemical imports will advance faster than exports in 1994.

One thing hurting the U.S. chemical industry's trade performance this year is that exports of the "big dollar" chemical categories, such as organics and synthetic resins, are showing relatively low growth. The larger growth rates are generally confined to smaller categories that don't contribute as much to the export totals. This trend has become apparent over the past few years, and is likely to continue.

For instance, organic chemicals are the largest single chemical export category, accounting for 25% of total chemical exports last year. But in 1988, organics' share of chemical exports exceeded 30%.

That share has been declining steadily ever since. This year, it probably will drop even further, because exports of organic chemicals are expected to increase only 0.5% to just over $11 billion.

Among the largest chemical export categories, only medicinals and pharmaceuticals are faring well this year. Exports of these materials will probably increase 7.3% to $5.7 billion.

Meanwhile, exports of such specialty chemicals as dyes and coloring materials, essential oils, perfumes, toilet preparations, and cleaning materials are growing faster than the all-chemical average in 1993. Exports of dyes and coloring materials, for instance, will increase 5.8% to almost $2 billion. But product categories such as these represent only a small percentage of the total export pie.

Behind this less than stellar performance of total chemical exports are weak economies in some major overseas markets. The European Community (EC) is a good example. Last month, EC commissioner Henning Christophersen revised forecasts made only this past summer. What they show is no surprise. Starting in summer 1992, the economies in most EC countries deteriorated sharply and have yet to recover. Gross domestic product (GDP) will be down 0.4% this year, on average.

Most economic indicators still are hovering at historically low levels, which to Christophersen suggests sluggish economic activity for the next few months. However, he believes that the economic slump may be leveling off and that the EC may have seen the trough of the recession. He sees a chance for a moderate economic recovery next year.

Even that small increase will come too late to help this year's U.S. chemical exports to the EC. As a bloc, the EC is the U.S. chemical industry's largest single market. Last year, 27% of U.S. chemical exports found markets in EC countries.

This year, however, U.S. chemical exports to the EC will drop 7.6% to about $11.1 billion. EC's share of the total will slip below 25%.

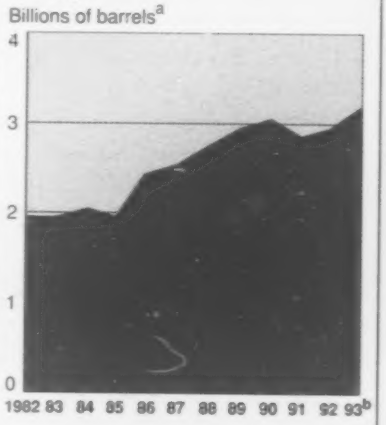
On a percentage basis, the largest decrease in chemical exports will be in exports to communist Asian countries, nearly all to China. At $735 million, these exports will be 39% lower than they were last year.

Chemical exports to other, booming markets of Asia, such as Malaysia and Thailand, aren't growing as fast as they have been. Several Asian countries are starting to supply at least part of their own markets from their own chemical plants. And even the high-flying Asian economies are starting to cool down a little.

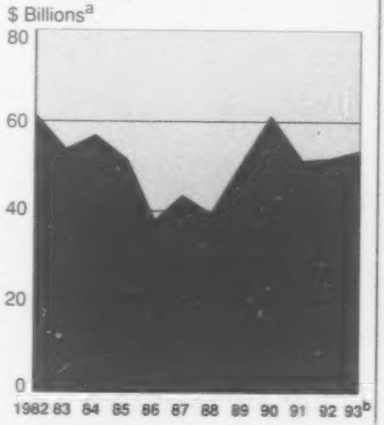
As a result, U.S. chemical exports to Asia, which advanced 9.2% in 1991, slipped 1.6% last year and likely will increase only 2.6% this year. Still, that adds up to a hefty $7.2 billion.

Canada is the brightest spot in the U.S. chemical trade picture. Chemical exports to Canada, facing little or no tariffs as a result of the U.S.-Canada Free Trade Agreement, will jump 12% in 1993 to $8.2 billion. That's good news for U.S.

U.S. oil imports will rise this year . . .

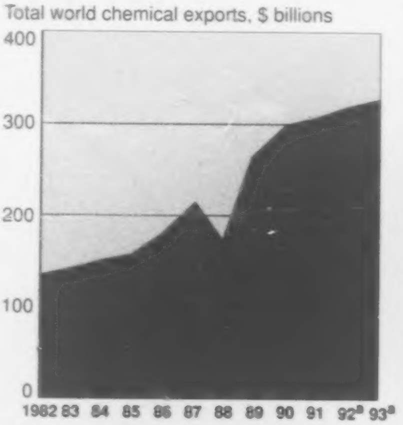


. . . pushing up the cost of oil imports

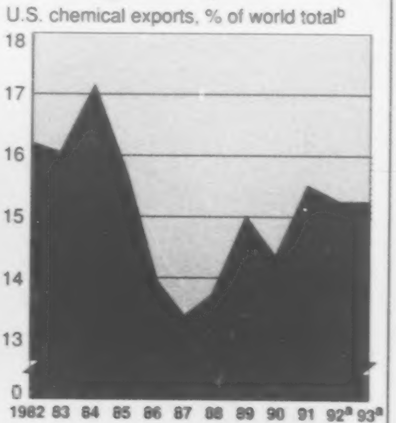


a All petroleum products. b C&EN estimates.
Source: Bureau of the Census

World chemical exports manage slight gain . . .



. . . as U.S. market share stands pat this year



a C&EN estimates. b Defined as U.S. chemical exports as percentage of world chemical exports less U.S. chemical imports.
Sources: United Nations, Organization for Economic Cooperation & Development, European Community, Japanese Ministry of International Trade & Industry, Bureau of the Census

Chemicals continue to be the trade category with the largest surplus

	U.S. exports				U.S. imports			
$ Billions	1993[a]	1992	1991	1990	1993[a]	1992	1991	1990
Machinery & transport equipment	$205.2	$200.9	$187.4	$172.5	$254.1	$232.0	$210.8	$208.0
Miscellaneous manufactures	49.8	48.0	43.2	39.3	102.4	95.0	83.4	81.5
Chemicals	44.9	44.0	43.0	39.0	29.2	27.7	24.2	22.5
Manufactured goods classified by material	36.6	36.3	35.6	31.7	65.5	60.4	57.4	59.9
Food & live animals	32.0	32.9	29.6	29.3	23.0	22.6	22.0	21.9
Crude materials, inedible except fuels	24.7	25.4	25.5	27.0	15.5	14.0	13.1	14.5
Mineral fuels & lubricants	10.1	11.1	12.0	12.2	58.2	55.0	54.3	64.5
Beverages & tobacco	6.4	7.1	6.8	7.1	5.8	5.4	4.8	4.6
Animal and vegetable oils, fats & waxes	1.4	1.4	1.1	1.2	1.2	1.1	0.9	0.8
Other	21.0	18.3	16.8	16.2	20.1	19.3	17.2	16.8
TOTAL	**$457.2[b]**	**$448.2[b]**	**$421.9[b]**	**$394.0[b]**	**$575.0**	**$532.5**	**$488.1**	**$495.0**

a C&EN estimates. **b** Includes reexported imports not included in individual categories. **Source:** Bureau of the Census

chemical companies because Canada is the largest single-country export market for U.S. chemicals.

Exports to Latin America, another major marketing region for U.S. chemicals, also are faring well this year. In 1993 they will amount to about $7.8 billion, 7.5% higher than last year.

One reason, of course, is the booming market for U.S. chemicals in Mexico. Mexico already is the third largest country market for U.S. chemical exports. They will jump again this year, this time by more than 8% to $3.4 billion.

Chemical exports to Mexico, in fact, will have almost doubled in the past five years. This explains why the chemical industry has supported the North American Free Trade Agreement (NAFTA) and why the industry fought so hard to help push NAFTA through Congress.

Now, with the NAFTA battle won in Washington, the chemical industry's small cadre of trade advisers are turning their attention to Geneva. There, negotiators from some 110 countries are making yet another 11th-hour effort to salvage the seven-year-old Uruguay round of the General Agreement on Tariffs & Trade (GATT) multilateral trade negotiations.

The deadline for completing the negotiations is Dec. 15. At press time, it appeared that negotiators would be able to resolve the several bitterly contested issues and meet that deadline.

The chemical industry certainly hopes so. Larry R. Gess, director of world trade for Nalco Chemical, recently told the Trade Subcommittee of the House Ways & Means Committee that the Uruguay round is "the engine we need to pull us out of the economic quagmire" in which international trade is languishing.

Gess calls the potential trade benefits that could spring from a successful Uruguay round "staggering." In scope and impact, he says, a Uruguay round pact is likely to have many times the benefits of a regional trade agreement such as NAFTA.

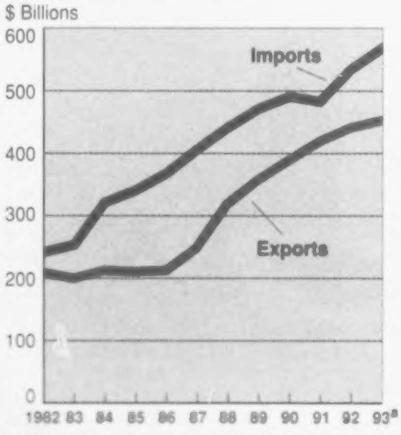
The U.S. chemical industry has long been a strong supporter of the Uruguay round. It still supports the "draft final agreement"—the so-called Dunkel text. Issued in December 1991, this text, named for Arthur Dunkel, who was then the director general of GATT, was supposed to have been the basis for concluding the negotiations.

But several countries, including the U.S., have called for serious changes in the Dunkel text. This opened up several cans of worms, some of which are still unresolved. The U.S. chemical industry's support for the Dunkel text is premised on negotiating a reasonable market access agreement that covers both tariffs and nontariff barriers. Market access is one of the major issues still being negotiated.

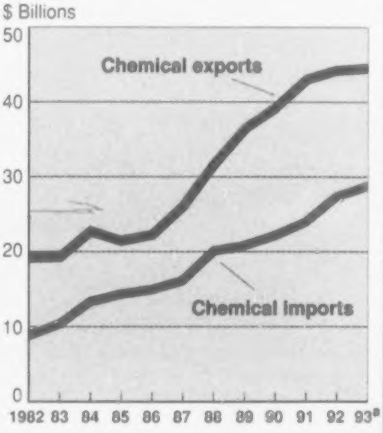
Agricultural trade has long been—and still is—a major stumbling block. Not all issues relating to services trade have been resolved. And recently, antidumping has emerged as another big issue.

Still, Peter D. Sutherland, director general of GATT, now thinks that negotiators can reach agreement by the Dec. 15 deadline. Based on indications that the U.S. may dilute its hard-line stance and compromise with France over cuts in farm subsidies, trade observers are cautiously inclined to agree. ☐

U.S. trade deficit continues to rise . . .

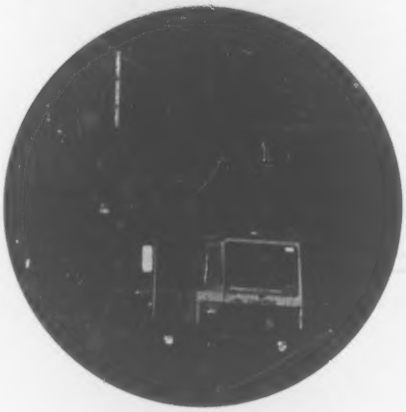


. . . while chemical trade surplus shrinks



a C&EN estimates. **Source:** Bureau of the Census

EUROPE



Definite Though Modest Recovery Forecast For 1994

Overcapacity and weak economies will continue to exact toll on European chemical companies

Patricia L. Layman, C&EN London

"Many chemical executives see plant shutdowns rather than growth in demand as the best cure for present excess capacity." That was the analysis of C&EN's World Outlook for the Western European chemical industry 11 years ago—in its issue of Dec. 20, 1982.

Similar problems of structural capacity, exacerbated by economic recession, face the chemical industry's executives as they come to the end of a depressing 1993. Profit-and-loss accounts for petrochemical and basic chemical producers have been liberally splashed with red ink this year, even more so than last. Chemical companies with pharmaceutical interests, which historically have provided extra buoyancy to results, have been hit by changes in government regulations. As for the outlook, the hope is that the economic recovery predicted for Western Europe in 1994 does, indeed, come to pass, to bring encouraging news back to chemicals.

Preliminary data indicate that chemicals production in Western Europe dipped 1 to 2% overall in 1993 from 1992 levels, paced by a 3% drop in production in the chemical industries of Germany, Italy, and the Netherlands, and a 5% drop in chemical output in Belgium. Of the countries with major chemical industries, only the U.K. showed any strength, with chemical production growing 3%, as the country emerged from recession; it had been one of the first countries to plunge into recession.

Now, as they ready early-year forecasts for 1994, economists throughout the Western European chemical industry are fighting their traditional optimism, predicting flat output levels or only very modest growth. A sluggish recovery throughout the region, and weak prices for chemical products, will also mark the upcoming year, the forecasts predict.

As Peter Vogtländer, chemicals coordinator at Shell International Chemical Co., put it at the Society of Chemical Industry's European annual meeting in Rome in October, fundamental structural problems are dogging the industry. "Without these fundamental problems, the solution would simply be to bring supply and demand closer into balance." But that, he said, would be a short-term fix: "If we want to achieve a sustainable improvement, we need to get to the root of the structural problem of cost competitiveness."

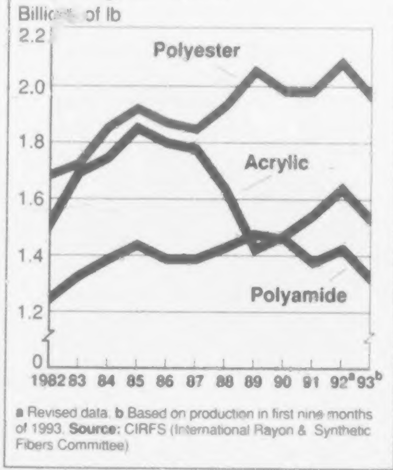
His colleague Pierre Yves Masson, head of chemicals international marketing at Shell, shares that assessment of the industry's problems. "The problems of the chemical industry are related to the economy," he says. "But the problem is not directly the economy, but the poor investment strategy of the companies, aggravated by the economy. When an industry is well managed, it can go through severe economic conditions—[as did] the oil industry, for example. The economy will only influence, it is not the main factor."

Petrochemical producers are waiting to see what the coming year will bring, in fact, in the way of restructuring—of cracker closures or manufacturing withdrawals. Probably the potentially most promising means of getting the process under way is an initiative that has been developed by the Association of Petrochemical Producers of Europe (APPE), a group under the umbrella of CEFIC, the European Chemical Industry Council, in Brussels.

Details have not been publicly revealed to date, but the initiative involves a restructuring fund to which member companies will contribute and from which grants can assist companies in closing capacity. The fund, reported to be a target amount of about around $300 million, must be agreed to unanimously, and that has proven to be a tough requirement. At APPE's meeting in November, a final-approval vote was divided, with about 80% of the members backing the plan. According to at least one corporate member, "We believe this is very encouraging, and we hope by mid-December APPE will have full approval."

If the vote goes ahead at this month's meeting, APPE can present the concept to

Man-made fiber output will sag in 1993



a Revised data. b Based on production in first nine months of 1993. **Source:** CIRFS (International Rayon & Synthetic Fibers Committee)

Major European countries have serious unemployment problems

	Number of unemployed[a] (millions)	% unemployment[a]
EUROPEAN COMMUNITY		
Italy	4.58	10.9 %
France	3.00	10.8
U.K.	2.87	11.4
Spain	2.52	21.8
Germany[b]	2.17	5.6
Belgium	0.51	9.5
Netherlands	0.38	8.1
Portugal	0.33	5.2
Denmark	0.33	10.5
Ireland	0.29	18.3
Greece	0.15	7.7[c]
Luxembourg	0.003	2.8
TOTAL	**17.13**	**10.4 %**
U.S. UNEMPLOYMENT RATE		**7.0 %**
JAPAN UNEMPLOYMENT RATE		**2.5 %**

a June 1993 data from Commission of the European Community
b Excludes eastern Germany. **c** Unemployment rate for 1992

the antitrust authorities in the Commission of the European Community (EC).

In a way, the proposed restructuring would mirror the restructuring of the Western European fibers industry in the 1980s. There are still problems with overcapacity in some fiber sectors, but the industry is now much healthier than it was at that time. Its problems today reflect a geographical shift in markets, as textile customers have relocated to low-wage areas in Southeast Asia, for example. And this year's European fibers output has been affected by an abrupt loss of business from Chinese buyers, with a resulting scramble for business disrupting normal import-export patterns.

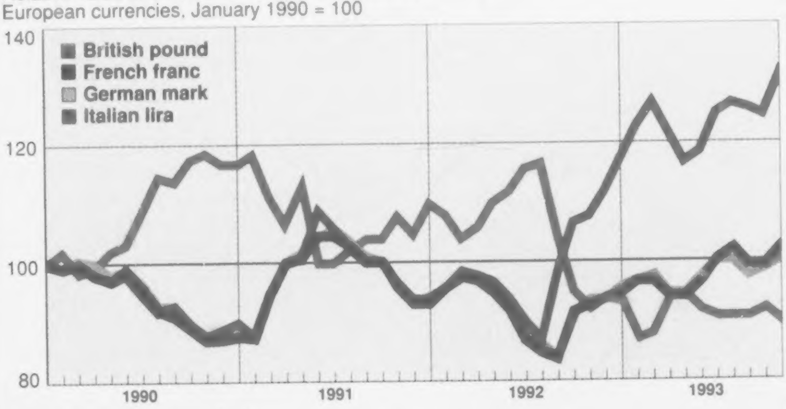
For the petrochemical industry, there has been an almost built-in excuse for inaction, given the fact that, in the past, officials at the EC Commission held hard-line antitrust views. But the atmosphere in Brussels has changed, observes Simon Woolley, general manager for strategic planning at BP Chemicals. "There are EC laws you have to live with, but there is scope for interpretation. We get some feedback that officials there will be realistic [about any restructuring proposals]. Anything that has companies doing things in a collective way will need EC approval. But it is in Europe's interest to have a competitive petrochemicals industry, and I believe that European politicians understand that."

Exactly how helpful the APPE plan would be is arguable. Some industry analysts in London, for example, are convinced the plan is just the ticket for the industry. Others are less sanguine.

For example, Tony Church, a chemicals analyst in the London offices of broker Wertheim Schroder, doubts that the APPE initiative will be much help. "Pricing power will continue to be in the hands of customers," he says. "Companies will continue to suffer. How long depends on how much pain there is—they seem to want to stay in these businesses."

Dollar stabilized and strengthened in 1993

Relative value of U.S. dollar versus four Western European currencies, January 1990 = 100



Source: International Monetary Fund

As he sees it, the outlook for the European chemical industry in 1994 is "bloody awful." There will be a very slight pickup in demand in the second half, he predicts. "Just a little, essentially, the start of a slow recovery. Companies with exposure to the U.S. will benefit more than others as the U.S. recovers more quickly."

The immediate problem during the past year for the industry has been low selling prices, which affect profit margins. As Shell's Masson observes, "The main problem is the selling price. We have not seen a collapse of the market: Volumes are not bad, but people are not reasonable—they want to keep market share at any price." Things are getting better, now, he says, as warehouses empty and production declines some.

In his statistical review of the European chemicals scene in October, Church noted that prices have been particularly hard hit in 1993. "After a second quarter when prices rose a little from the very depressed levels of early 1993, there were lingering hopes that these higher levels would be held in the third quarter, to be followed by further rises in the fourth quarter. The seasonal slump in August [hit hard] the third quarter and, although September started brightly enough with a number of announcements of price rises, the follow-through has been largely nonexistent," he observed. Polyvinyl chloride, he concluded, was the only polymer that had managed to climb back to a break-even point.

Despite his somewhat gloomy outlook, however, Church's projections into 1994 show that he expects some positive results to begin to filter through to the major chemical producers. Tables showing year-on-year changes from 1991 to 1992, and 1992 to estimated 1993 results, for example, are littered with minus signs, with widespread drops in sales, operating profits, and pretax profits. His projections for the major chemical producers for 1994, however, show mostly positive rates of growth.

For the European chemical industry, the past year's shocker has been the state of the German economy, and the consequent effects on its chemical industry, by far the largest in Europe.

According to Wolfgang Hilger, chairman of Hoechst, sales volumes for Hoechst in the first three quarters of the year in Germany were well below the previous year's level, and that softness in demand led to further price reductions. This meant that, for Hoechst, "particularly in our plastics, fibers, chemicals, and synthetic resins and paints activities, we had to cope with appreciable declines in sales."

"Sending out the right signals this year is a task that lies in the hands of our politicians and of course the representatives of both sides of industry. It is of utmost significance not only to the existence of the chemical industry but also to a number of other industrial sectors in eastern and western Germany," he contended—developing at his Hoechst autumn press briefing a theme he has also stressed during his two-year stint as head of the German Chemical Industry Federation. That stint is now drawing to a close.

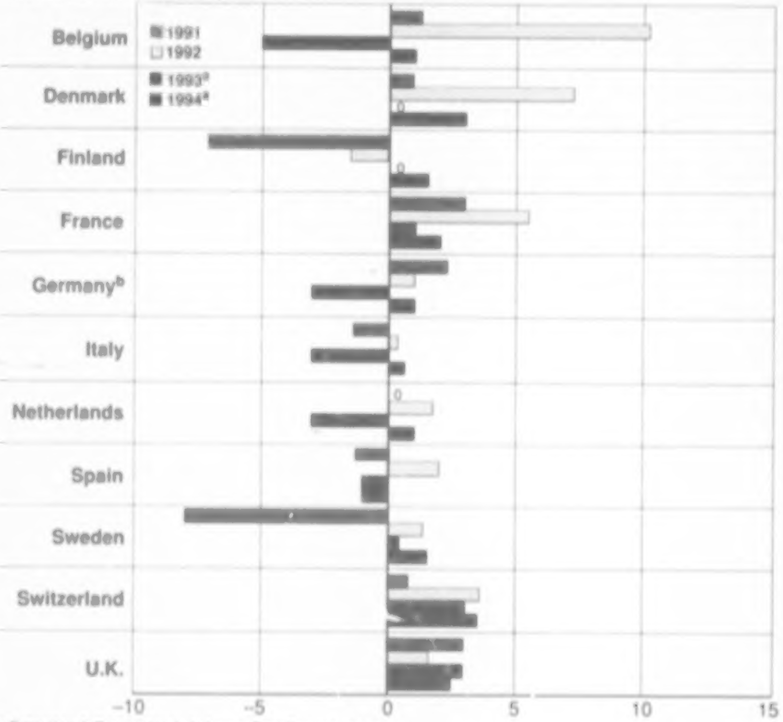
Jürgen Strube, chairman of BASF, cited German government health care reforms that came into effect at the beginning of 1993 as one of the major factors that affected the country's pharmaceutical industry during the year. The original plan was to trim 3 billion deutsch marks—roughly $1.8 billion—by curtailing physicians' prescriptions for drugs, which are paid by the government. So successful was the plan that it will have saved 7 billion marks, as physicians switch from prescribing patent-protected drugs to generics. That is good for the government, which is trying desperately to cut its own spending. The long-term implications for pharmaceuticals R&D, however, are not clear.

Given the combined forces of reduced pharmaceuticals sales, lower petrochemical prices, and lower demand as a result of the German recession, German chemical companies have begun tackling some of the same problems their counterparts in the U.S. and the U.K. grappled with earlier. They have begun pruning their product portfolios, carefully, in small bits and pieces, during the past year. And they have finally begun trimming employment.

For example, at Bayer, group personnel expenses were down 3% for the first nine months, and those at parent company Bayer A.G. were down by more than 8% from the comparable period last year. There was no possibility for creating additional jobs in the near future, however desirable this would be from an economic and social viewpoint (given the high level of unemployment in Germany), says Manfred Schneider, Bayer chairman.

Chemical output projected to pick up modestly next year

% change from previous year



a Estimates. b Does not include former East German states.
Sources: European Chemical Industry Federation, C&EN estimates

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Calculated for both the western and eastern parts of the country, unemployment is currently running at 3.5 million. And that figure is expected to rise to 4 million next year.

Germany's 4 million will put it in the same league as Italy, which leads in total unemployed among the EC countries. Italy's total is rising inexorably, as government-owned companies, historically used as vehicles for patronage jobs, prepare themselves for privatization.

Meanwhile, pangs of unemployment are sharp throughout Europe. The October figures for France, for example, show joblessness of 12%, up from 11.8% in September; the total was about 3.3 million French citizens registered with the national agency for employment. And in Finland, unemployment in September 1993 was 19.2%, or 490,000 people unemployed.

In fact, the nearly 18 million unemployed people in Western Europe could form a country that would be the sixth largest in the EC, after Spain's 40 million population, and larger than the Netherlands' 15 million.

Things are not expected to become markedly better as long as Germany—the country which had been looked to as the engine pulling the European economy along with it—is in recession. And experts are divided as to when that will end.

A report published in October from Germany's six leading economic institutes predicted that the German economy will grow 1 to 1.5% next year; this past year, it shrank about the same amount.

On the other hand, Germany's council of economic advisers issued its annual report in November, predicting zero growth and rising unemployment in the western part of the country in 1994. Reasons for the stagnation: declining exports and a loss of confidence by the business community in the German economy, resulting in a sharp drop in investment.

Confirming that lack of confidence, BASF's Strube noted: "We do not share the optimism expressed in the autumn report of the German economic institutes on growth in 1994. Although volumes and sales revenue are beginning to stabilize slowly at a low level, it is too early yet to talk about the light at the end of the tunnel—there is a glimmer of hope, perhaps, at best.

"We in Germany expect no more than a minimum increase, in real terms, in the gross domestic product for 1994. In Western Europe, we believe that an increase of less than 1% is a possibility. There is unlikely to be significant growth in Germany and Western Europe before 1995."

Nevertheless, even if the German institutes' forecasts come true, the EC's economy is not expected to expand enough to put many of the community's unemployed back to work. That will mean a continuing draw on countries' purse strings for funding programs of health, social security, and unemployment payments, as well as new initiatives on education and retraining.

The emphasis for the EC, says a draft of the community's policy document on competitiveness, growth, and employment—which sets a target of halving unemployment to 5% by 2000—must be on "trading up" into higher value-added, better quality goods and services, rather than downgrading social protection and welfare provisions. But in a sense, that conflicts with the need seen by Europe's various industries to reduce costs to ensure competitiveness.

"It will be a long time before we in European industry can be competitive again," frets one chemical industry manager. "Look at our wage costs or social costs. That is stopping us, and it will stop our customers, such as the car industry.

"If Thailand is becoming too expensive, and people want to go to Vietnam," he adds, "it indicates the degree of uncompetitiveness we have in Europe. Until this is corrected by productivity gains, we will continue to suffer. The EC is losing its grip on what is going on in European countries."

For the coming year, companies agree that joint ventures will become increasingly important. No matter what happens to the APPE restructuring fund, joint ventures are one way to tackle the industry's—companies'—problems.

This past year, for example, has seen the merger of petrochemical and polyolefin operations of Finland's Neste and Norway's Statoil. Shell and Montedison are discussing a joint venture in polyolefins. And swaps of operations are increasingly seen as another way to trim the large number of producers in the European chemical industry.

As one manager involved in joint-venture discussions puts it, "The problem in the industry is too many players, with too many small plants, not well located strategically." In a venture or alliance, by contrast, each company doesn't feel obliged to have its own plant, so decisions can be made to concentrate on those that are most strategically located.

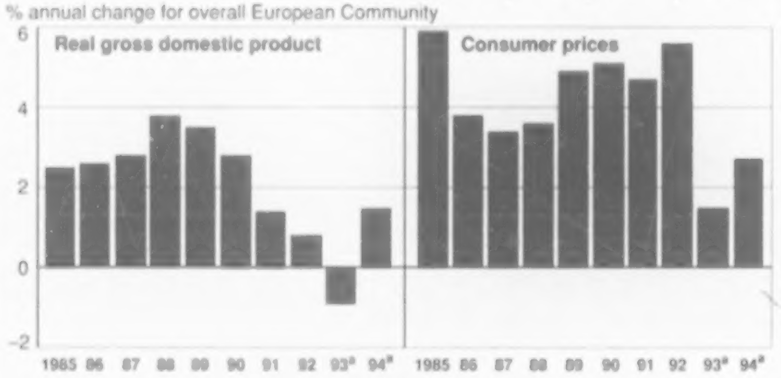
Sometimes it's a matter of corporate philosophy, points out BP Chemicals' Woolley. For example, "BP Chemicals is historically a joint-venture company—we started with a venture between British Petroleum and Distillers. We don't have a strategy that says we want to do it on our own."

In fact, he adds, "opportunities absolutely abound for ventures, like the recycling consortium [to recycle plastics waste into olefin feedstocks]. You don't just do one or two or a dozen, and say you are finished. There will always be some coming along. Internationally, it is the essential way to do it—work with partners."

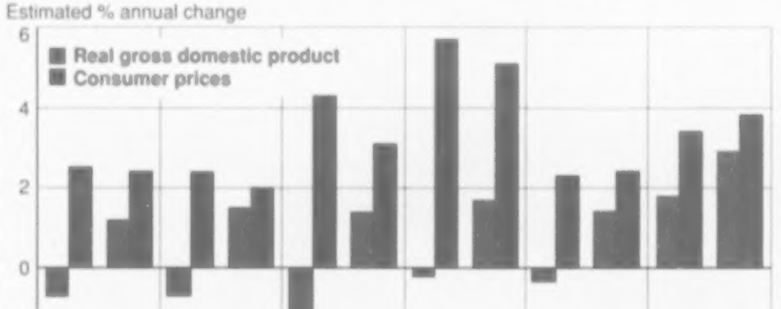
And, of course, underlying all the industry's other activities will be the attention it must pay to public concern about environment and corporate responsibility. Not just a flashy one-year program, this is part of the plugging-away effort to which the industry has committed itself, via Responsible Care programs and environmental reports, throughout Europe.

As Woolley puts it, "The issue of public trust remains crucial. It remains as an issue. Public perception of chemicals is pretty low, compared with what the industry is genuinely doing for society and the public. The industry still needs to get its message across." ☐

Flat European economies will begin to pick up next year . . .



. . . as individual countries survive troubled 1993



a Estimates. **Sources:** Commission of the European Community, Organization for Economic Cooperation & Development

JAPAN

Once Booming Economy Struggles Through Tough Times

Severe recession continues and recovery probably won't start soon

Earl V. Anderson,
C&EN Northeast News Bureau

Japanese chemical companies are trying every trick in the book to weather the country's severe and persistent recession. They are cutting back production, closing plants, and delaying projects that are on the drawing boards. They are joining in cooperative production and marketing arrangements.

Some companies are starting the painful restructuring process that many U.S. chemical companies have already gone through over the past few years. Some are trying to augment their weak domestic sales with exports, which is not an easy task in the face of strong international competition and a strong yen. Some are even suspending dividends—anything to stem the flow of red ink that has become commonplace in the Japanese chemical industry.

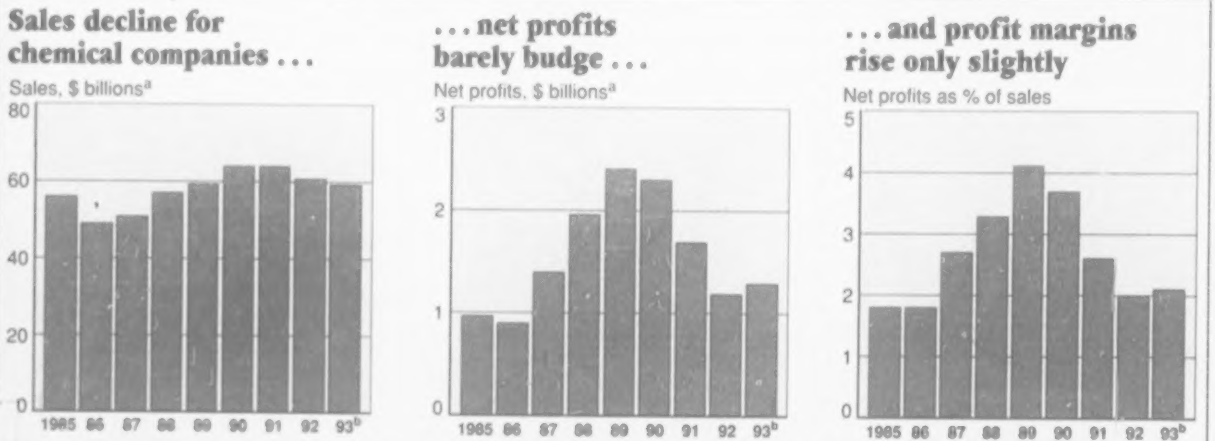
These actions may help keep the performance of Japanese chemical companies from getting worse than it already is. But they aren't helping it to get better. Chemical companies in Japan, particularly those that depend heavily upon their basic petrochemical businesses, are taking a drubbing.

Early C&EN estimates of combined sales and income for 12 of Japan's leading chemical companies indicate that, although chemical industry sales will probably drop, profits may rise almost 5% during this fiscal year, which ends next March. The estimates are based on data compiled by Toyo Keizai, the financial publishing house, in its Japan Company Handbook.

Toyo Keizai's data and C&EN's early estimates may be much too optimistic, however. Recent company reports reveal that the bloodletting may be much more severe than early estimates indicate.

Faced with sluggish demand for synthetic fibers and resins, Kuraray expects its fiscal 1993 sales to be 2% lower than last year and has lowered its profit estimate by about 10%. Teijin anticipates its pretax profits falling a hefty 34% for the year, which would bring them in well below earlier forecasts. With sales through the first half of the year off by 9%, Teijin's major problem is weak demand in the textile arena.

Japanese petrochemical giant Mitsubishi Kasei thinks that its sales won't decline this fiscal year. But it can't say the same about profits. It expects to lose almost $19 million this year, the company's first loss since its stock was listed on the Tokyo Stock Exchange in 1950.



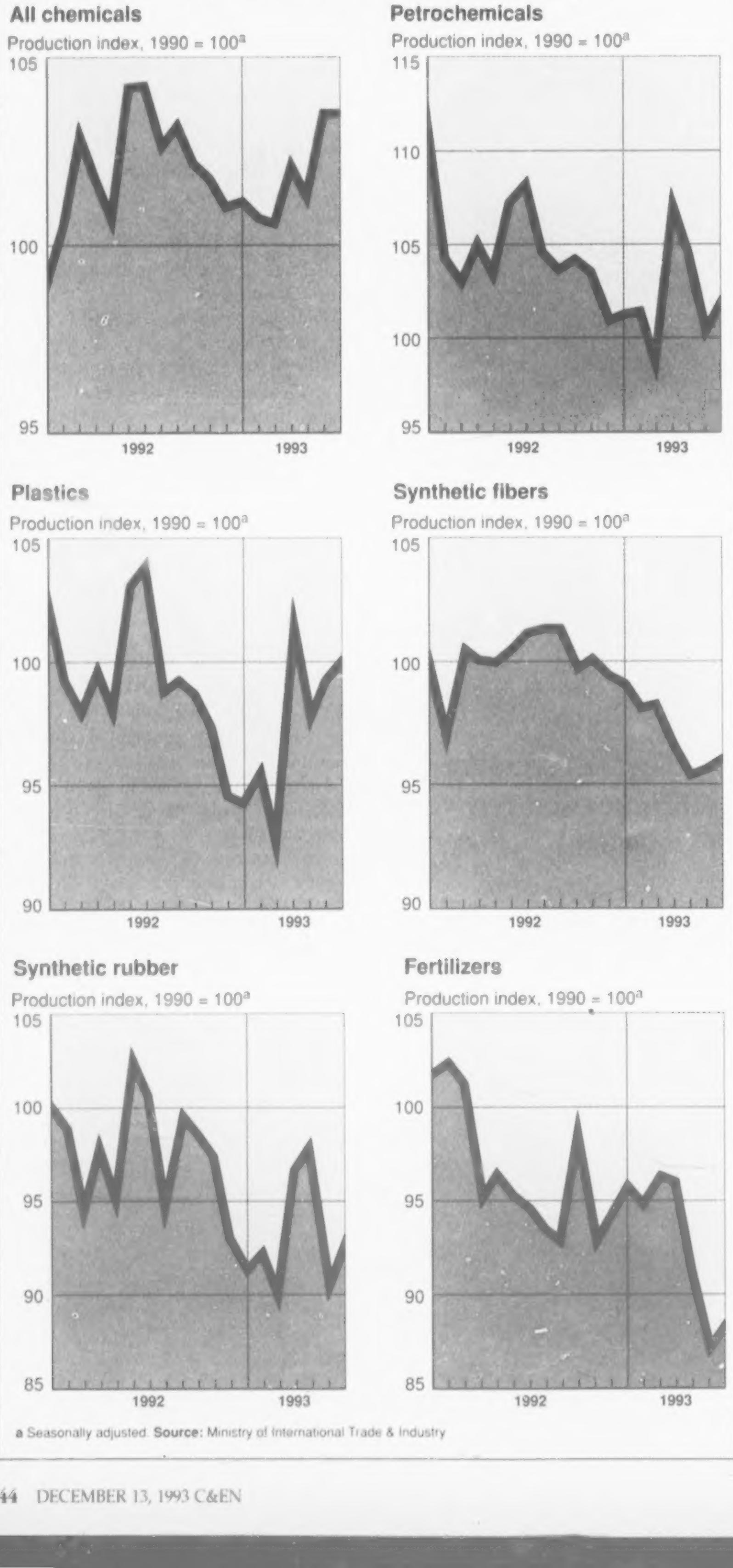
Sales decline for chemical companies . . .

. . . net profits barely budge . . .

. . . and profit margins rise only slightly

Note: Based on the results of 12 leading Japanese chemical companies: Asahi Chemical Industry, Dainippon Ink & Chemicals, Hitachi Chemical, Mitsubishi Kasei, Mitsubishi Petrochemicals, Mitsui Toatsu Chemicals, Sekisui Chemical, Showa Denko, Sumitomo Chemical, Takeda Chemical Industries, Teijin, and Toray Industries. The fiscal year for most, but not all, of these Japanese companies ends March 31 of the following year. **a** Converted at recent exchange rate $1.00 = 106.69 yen. **b** C&EN estimates. **Source:** Toyo Keizai

Japan's chemical production remains weak this year



All chemicals Production index, 1990 = 100[a]

Petrochemicals Production index, 1990 = 100[a]

Plastics Production index, 1990 = 100[a]

Synthetic fibers Production index, 1990 = 100[a]

Synthetic rubber Production index, 1990 = 100[a]

Fertilizers Production index, 1990 = 100[a]

a Seasonally adjusted. **Source:** Ministry of International Trade & Industry

At many major Japanese chemical companies, the story is the same. Weak demand is keeping a lid on sales. And low prices are driving profits down.

And it may be later, rather than sooner, before the economic tide turns. Japan's economy has been stuck in a recession for more than two years. Japan's Economic Planning Agency determined that the recession started in April 1991. And economists now expect the recession to linger longer than they originally thought.

Recent trends indicate that production will decline further before it starts rising, that consumption and capital spending will drop further, and that the employment outlook will worsen.

Earlier in the year, conventional thinking held that Japan's economy would bottom out toward the end of this fiscal year. Now the target is the fiscal year ending March 1995, with the consensus being that recovery, if it comes, will come in the latter part of that year. Some private-sector economists even believe that the economy may not hit bottom until even the following fiscal year.

Chemical industry executives in Japan certainly hope that relief comes sooner rather than later. They want to see more product flowing out of their plants, something that won't happen unless demand perks up.

If April 1991 was, indeed, the turning point for the Japanese economy, the all-chemical production index for a recent month was up a scant 1% over the April 1991 index. That's a pittance in more than two years.

And not all sectors of the industry were even able to share in that small gain. Over the same time span, the production index for petrochemicals is down 4.9%, while the index for plastics is down 2.6% and that for synthetic fibers is down a hefty 6.3%.

Very few chemicals will make it through 1993 with a larger output than they had in 1992. Production of ethylene, a bellwether chemical and cornerstone of Japan's important petrochemical industry, will fall 5.5% this year to about 5.8 million metric tons. In September, the latest month for which statistics are available, ethylene production was just under 436,000 metric tons. That's the lowest monthly output since 1989 and it knocked Japan's ethylene plant operating rate below 80%.

Ethylene's problems reflect the weak demand that its derivatives are facing in the domestic market and, to a lesser extent, in the export market. Output of polyethylene, for instance, probably will be about 7% lower this year than it was in 1992. Ethylene demand for ethylene oxide and glycol is off, and polystyrene output will be lower this year. Among ethylene's major derivatives, only polyvinyl chloride may be up—and this by only a minuscule 0.2%.

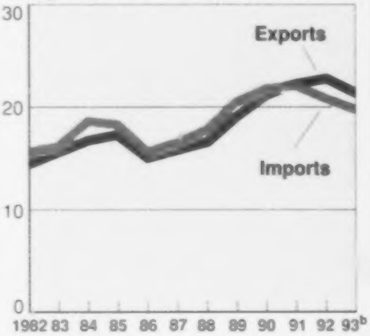
Production of most chemicals will dip

Thousands of metric tons, unless otherwise indicated	Production 1993[a]	1992	1991	1990	1989	% change 1992–93
INORGANIC CHEMICALS						
Ammonia	1,700	1,788	1,855	1,831	1,831	–4.9%
Ammonium chloride	230	233	239	246	274	–1.3
Ammonium sulfate	1,700	1,830	1,781	1,803	1,717	–7.1
Calcium carbide	260	270	303	294	344	–3.7
Calcium superphosphate	405	396	420	472	454	2.3
Carbon black	705	771	793	783	779	–8.6
Chlorine, liquid	925	978	1,027	1,042	1,009	–5.4
Hydrochloric acid	680	706	702	637	571	–3.7
Nitrogen[b]	8,865	9,129	8,767	8,299	7,856	–2.9
Oxygen[b]	8,040	8,067	9,000	8,787	8,384	–0.3
Sodium carbonate	1,040	1,057	1,104	1,135	1,105	–1.6
Sodium hydroxide	3,760	3,866	3,905	3,917	3,674	–2.7
Sodium silicate	715	722	787	788	756	–1.0
Sulfuric acid	6,865	7,100	7,057	6,887	6,885	–3.3
Titanium dioxide	245	252	279	280	275	–2.8
ORGANIC CHEMICALS						
Acetaldehyde	345	391	384	384	356	–11.8
Acetic acid	475	451	458	462	432	5.3
Acetone	340	377	369	334	337	–9.8
Acrylonitrile	600	621	604	593	611	–3.4
Benzene[c]	3,150	3,309	3,050	2,768	2,672	–4.8
Butadiene	815	851	847	827	827	–4.2
Butanol	380	371	334	300	291	2.4
Caprolactam	515	548	531	509	469	–6.0
Cyclohexane	625	632	584	629	656	–1.1
Dioctyl phthalate	270	297	305	295	293	–9.1
Ethylene	5,770	6,104	6,142	5,810	5,602	–5.5
Ethylene dichloride	2,690	2,708	2,642	2,660	2,464	–0.7
Ethylene glycol	530	560	609	501	548	–5.4
Ethylene oxide	675	721	760	674	681	–6.4
Methanol	75	34	77	84	82	120.6
Octanol	310	327	295	283	285	–5.2
Phenol	530	538	495	403	423	–1.5
Phthalic anhydride[c]	150	165	162	161	160	–9.1
Propylene	4,270	4,536	4,431	4,215	4,036	–5.9
Propylene glycol	285	302	301	298	285	–5.6
Styrene	2,190	2,182	2,227	2,161	1,990	0.4
Terephthalic acid	1,565	1,425	1,434	1,338	1,200	9.8
Toluene	1,150	1,150	1,119	1,078	1,075	0
Toluene diisocyanate	140	132	136	116	104	6.1
Urea	725	725	730	776	810	0
Xylene	3,230	3,203	2,918	2,652	2,488	0.8
PLASTICS						
Phenolic resins	325	356	383	385	375	–8.7
Polyethylene	2,775	2,980	2,982	2,888	2,712	–6.9
Polypropylene	1,915	2,038	1,963	1,942	1,719	–6.0
Polystyrene	1,985	2,005	2,121	2,097	1,997	–1.0
Polyvinyl chloride	1,985	1,981	2,055	2,049	1,972	0.2
SYNTHETIC RUBBER	1,330	1,388	1,377	1,426	1,352	–4.2

a C&EN estimates. b Millions of cubic meters. c Petroleum-based product only.
Source: Ministry of International Trade & Industry

Japan's chemical exports, imports both decline

Foreign trade in chemicals, $ billions[a]



a All data converted at recent exchange rate of $1.00 = 106.69 yen. b C&EN estimates.
Source: Ministry of International Trade & Industry

The picture isn't any brighter in Japan's chemical export business. Exports of the major polyolefins—low- and high-density polyethylene and polypropylene—were off about 10% during the first half of the year. Producers expect the export slump to continue for some time. Diminished demand, lower prices, and the strong yen are all contributing to the poor export performance.

The yen, in particular, is a big problem for all Japanese exporters. Typically, if a country's currency is weak, its companies tend to be more competitive in international markets. Strong currencies make them less competitive.

This year, the yen has become very strong. It started the year at about 125 yen to the dollar, then strengthened to almost 100 yen to the dollar before bouncing back to the 106- to 108-yen range.

Not only does this phenomenon make Japanese exports less competitive, it also makes Japanese export statistics more confusing. Japan's Ministry of International Trade & Industry (MITI) reports exports and imports in both yen and dollars. On a dollar basis, Japan's chemical exports will rise 5% and imports will grow 3.7% this year.

But on a yen basis, MITI data indicate that Japan's chemical exports will drop 6.2% and imports 6.4%. The yen-based data are closer to the truth. Additionally, although C&EN reports its data on Japanese chemical trade in dollars, it reflects MITI's yen data because data for all years are converted at the same (recent) exchange rate.

The immediate future of Japan's chemical industry, however, is much less confusing. Until Japan's economy recovers, its chemical companies must continue to find ways to cope with hard times and keep their losses to a minimum. ☐

CANADA

Exports Provide Boost For Chemical Firms

Particularly to the U.S., exports get the credit for improved sales and earnings despite sluggish economy

Earl V. Anderson,
C&EN Northeast News Bureau

Leaders in Canada's chemical industry will be watching closely on New Year's Day to see if the North American Free Trade Agreement (NAFTA) goes into effect as scheduled and if Canada is a part of it. They certainly hope so.

The reason is simple. Many Canadian chemical companies, particularly those in the petrochemical industry, have world-scale plants, but only a small-scale domestic market of some 27 million people. To survive, these companies must export. And more and more of their exports are heading into the U.S., where the market is about 10 times larger. This year, about 78% of Canada's chemical exports will go to the U.S., up from 67% in 1985 and from only 56% in 1980.

That's a big chunk of chemical business to protect. By being a part of NAFTA, Canada will be better positioned to do just that.

Canada, of course, has had a free trade agreement with the U.S. since Jan. 1, 1989. This Canada-U.S. Free Trade Agreement (FTA) was—and still is—controversial in Canada, just as NAFTA is.

But despite the naysayers, who claim that FTA, and not the recession, has caused massive job losses in Canada, the free trade pact has provided Canada's chemical industry with such benefits as preferential tariffs and, generally, better and more secure access to its critically important U.S. market.

The Canadian chemical industry has supported a Canadian role in NAFTA from the beginning. It feared that a NAFTA without Canada could potentially erode the market access benefits that it has achieved from the earlier bilateral agreement. And the industry wants to make certain that its marketing muscle in the U.S. isn't atrophied by a surge of new chemical competition from Mexico entering the U.S. on better terms than those already enjoyed by Canadian chemicals.

The Canadian Parliament approved NAFTA in May, but it still had to be officially proclaimed by the Prime Minister. Jean Chrétien, who now holds that position, wanted to make some changes in NAFTA involving energy, antidumping, and subsidy provisions.

But since the Liberal Party's overwhelming victory in Canada's October elections and NAFTA's victory in Congress, Chrétien has mellowed from his campaign rhetoric. Some, but not all, of the changes he wanted have been made. And he has approved the pact. Canada's trade minister, Roy MacLaren, says there's no need to delay implementing NAFTA on Jan. 1.

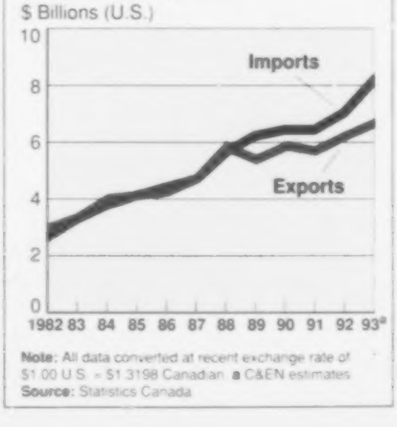
That should please Canada's chemical industry. Any improvement in its sales and profits next year will depend heavily on exports, particularly to the U.S. Du Pont Canada's third-quarter results indicate just how heavily some Canadian chemical companies depend on exports. Although third-quarter sales increased almost 13% from last year to $283 million in U.S. dollars, domestic sales increased only 5%. Exports, meanwhile, were up 24% over the same period last year and continued to be the largest contributor to Du Pont Canada's sales growth. In fact, exports accounted for 64% of the company's third-quarter product revenue.

Indeed, Canada's chemical exports are booming this year. By year's end, they likely will hit $6.8 billion in U.S. dollars, more than 10% ahead of last year. One reason for this export performance is the weaker Canadian dollar. Weak currencies tend to make a country's exports more competitive on international markets—and vice versa.

As fast as chemical exports are rising, however, Canada's chemical imports are growing even faster. They probably will rise almost 20% this year to $8.4 billion in U.S. dollars, saddling the country with a $1.6 billion chemical trade deficit. Three quarters of those imports originate in the U.S.

Nevertheless, exports have been an elixir this year for Canada's chemical industry. They are a big reason why some chemicals, particularly petrochemicals, will enjoy some gains in

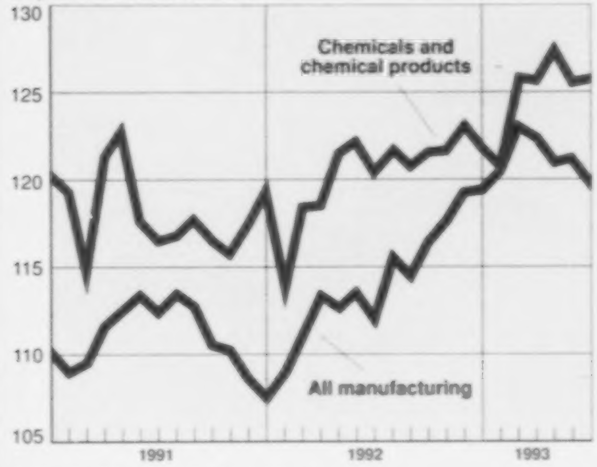
Canada's chemical imports outpace exports



Note: All data converted at recent exchange rate of $1.00 U.S. = $1.3198 Canadian. **a** C&EN estimates
Source: Statistics Canada

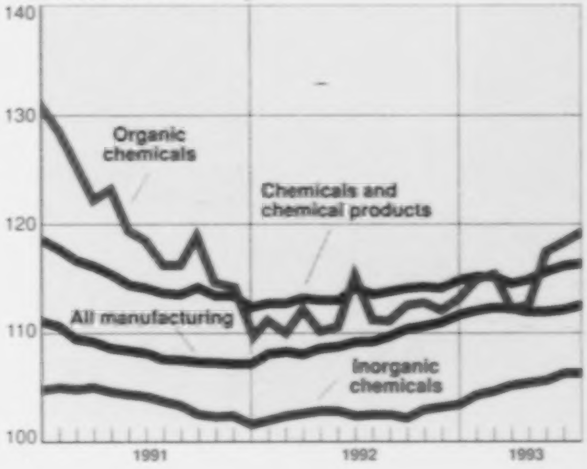
Chemical shipments pick up slightly . . .

Shipments index, 1985 = 100[a]



. . . and chemical prices start to firm

Price index, 1986 = 100



a Seasonally adjusted. **Source:** Statistics Canada

production, however small those gains may be. And they are why the output of other petrochemicals is not much lower.

Ethylene production, for instance, will be down only 0.2% this year. Output of two of its major derivatives, low-density and high-density polyethylene, will be down 0.6% and 2.0%, respectively. Their production would have been down even more were it not for exports.

And exports, along with cost-cutting measures, are the reason that third-quarter sales and earnings improved for most of Canada's major chemical companies, despite a still-sluggish domestic economy. Profits likely will continue to increase gradually during the fourth quarter as well.

According to one seasoned observer of the Canadian chemical industry, exports will help sales and profits improve even more next year. He believes that, with any kind of a pickup in the U.S. economy, excess capacity in the U.S. will be largely eliminated and the door opened for more imports from Canada. Not many foreign petrochemical companies can compete in the U.S. market with Canadian companies in Alberta.

An old cliche says that when the U.S. catches cold, Canada catches pneumonia. Reversing that thought, this observer thinks that, with any kind of an economic recovery in the U.S., "we (Canadian petrochemical producers) will be absolutely bloody booming."

That probably is an exaggeration, but there's no doubt that any U.S. economic recovery will be reflected in Canada's chemical fortunes. NAFTA may also help in a convoluted sort of way.

Canadian chemical producers don't expect their small chemical exports to Mexico to increase much for a long time. If NAFTA spurs the Mexican economy as it is supposed to, most of the increased Mexican demand for petrochemicals will be supplied from the U.S. Gulf Coast. However, Canadian chemical producers think that this will make less U.S. material available for the U.S. market and give them an opportunity to increase their exports to markets along the northern U.S. tier.

Certainly, Canadian chemical companies cannot expect much improvement in sales and earnings next year unless exports have another banner year. Canada's own economy has been recovering, but very slowly. Some industrial sectors, such as pulp and paper, construction, and mining, are still struggling. All are major markets for chemicals. □

Output is down for most major chemicals

	Production					
Thousands of metric tons	1993[a]	1992	1991	1990	1989	% change 1992–93
Ammonia	4,100	3,770	3,669	3,715	4,054	8.8%
Ammonium nitrate	985	1,015	963	1,031	1,056	–3.0
Benzene	675	686	712	762	670	–1.6
Chlorine	1,200	1,364	1,402	1,542	1,592	–12.0
Ethylene	2,515	2,521	2,425	2,434	2,317	–0.2
Hydrochloric acid, 100%	135	168	193	187	180	–19.6
Nitric acid	885	919	912	965	1,027	–3.7
Polyethylene, high density	635	648	458	364	303	–2.0
Polyethylene, low density	1,000	1,006	1,109	1,167	1,039	–0.6
Polystyrene	160	167	167	215	196	–4.2
Propylene	775	753	717	765	719	2.9
Sodium chlorate	770	633	695	659	593	21.6
Sodium hydroxide	1,270	1,428	1,498	1,650	1,679	–11.1
Sulfuric acid	3,515	3,225	2,953	3,311	3,560	9.0
Toluene	320	372	364	425	397	–14.0
Urea	3,015	2,550	2,397	2,490	2,402	18.2
Xylenes	265	339	391	514	432	–21.8

a C&EN estimates. **Source:** Statistics Canada

CHEMICAL & ENGINEERING NEWS

C&EN

DECEMBER 20, 1993

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NADPH
Arginine
NADP⁺
Citrulline
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NITRIC OXIDE

Biochemistry's unexpected new superstar
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CHEMICAL & ENGINEERING NEWS

C&EN

DECEMBER 20, 1993

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- Job outlook for new grads in chemical sciences and engineering continues bleak, according to Northwestern University and Michigan State University surveys. Page 5
- Researchers at Princeton's Plasma Physics Lab have produced a record 6 MW of controlled fusion power using the lab's Tokamak Fusion Test Reactor. Page 5
- Eastman Chemical has received the U.S.'s top prize for excellence in quality management—the Malcolm Baldrige National Quality Award. Page 6
- DuPont, Dow Chemical, and Northwestern University will team up to build and operate research facilities at the Advanced Photon Source nearing completion at Argonne National Lab. Page 6
- New Greenland ice core data contradict theory that rapid global warming and cooling occurred during the previous interglacial period, the Eemian. Page 7

COVER: Artist's conception of nitric oxide biosynthesis

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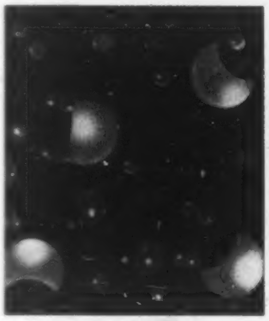
SPECIAL REPORT



Nitric oxide—a small, relatively unstable, and potentially toxic diatomic free-radical that does not contain carbon—appears to have messenger and effector roles in an astonishing range of physiologic processes, from neurotransmission to cytotoxicity. Page 26

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1155—16th St., N.W., Washington, D.C. 20036

Editor: Michael Heylin (202) 872-4501
Managing Editor: Madeleine Jacobs
Assistant Managing Editors: James H. Krieger, Janice R. Long, Rebecca L. Rawls, Donald J. Soisson, William J. Storck
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LETTERS

NAFTA bad for U.S. industry

Chemical Industry Medalist W. H. Clark (C&EN, Oct. 11, page 11) very forcefully endorses the North American Free Trade Agreement (NAFTA). His views, however, are parochial and do not represent the best interests of the U.S. as a whole. He has ignored, overlooked, or undervalued the vital interests of millions of blue-collar U.S. workers, and thousands of small U.S. businesses in textiles, metal tools, apparel, hardware, furniture, electric appliances, automotive parts and many other products. Many chemists are employed in these businesses.

He has totally disregarded any evaluation of environmental protection equity, comparative personnel safety, comparative environmental capital investment and operating costs (see C&EN, July 26, page 8), U.S. retraining, and environmental costs. Sen. Bob Kerrey (D.-Neb.), an advocate of NAFTA, admitted the Mexican agreement will cause loss of U.S. jobs and proposed a "strong federal commitment to job training."

Clark does not discuss the existing tremendous Mexican pollution of water, earth, air, and aquifers caused by present and past unsanitary Mexican municipal practices and by toxic contamination by petroleum operations and refining and industrial manufacturing [*Env. Sci. & Tech.*, **27**, 794 (1993)]

Industry in the U.S. cannot compete with industry in Mexico so long as Environmental Protection Agency, Occupational Safety & Health Administration, and Food & Drug Administration regulations are enforced in the U.S. but not in Mexico. U.S. companies operating in Mexico do not even obey the present weak Mexican environmental laws—a U.S. General Accounting Office survey of 12 such U.S. firms found that none bothered to comply.

Philip T. Gidley
President
Gidley Laboratories Inc.
Fairhaven, Mass.

First synthesis of nitrosyl azide

The news item "New oxides of bromine, nitrogen prepared" (C&EN, Nov. 29, page 51) moves me to write this letter. In the mid-1950s a group at the National Aeronautics & Space Administration's Lewis Research Center was speculating about how the next generation of hypersonic wind tunnels would be built. It would require high-mach-number air at very high stagnation temperatures. Prevalent practice favored ceramic blow-down tunnels. I proposed that nitrosyl azide would be an unstable analog of the nitrosyl halides and that its decomposition product would be virtually pure hot air. Used as a rocket monopropellant, it would provide, in the exhaust nozzle, a hypersonic high-temperature wind tunnel—a much better flight-condition simulator than anything else then being considered.

Accordingly, I asked a researcher in the section I headed, Harold W. Lucien, to attempt the preparation by a double displacement reaction using sodium azide and nitrosyl chloride. He explored several other synthetic routes as well. He produced a yellowish product with properties similar to those reported in the news item. In addition, he reported the results of difficult (because of explosions) measurements of a melting point range, the variation of vapor pressure with temperature, parts of the infrared spectrum, Trouton's constant, and other observations [*J. Am. Chem. Soc.*, **80**, 4458 (1958)]. If present measurements substantiate those of Lucien, and the substance is, indeed, nitrosyl azide, then its first synthesis should properly be attributed to him.

Lucien's work and my encouragement of it comes to mind now because recent interest in hypersonic flight has revived interest in hot wind tunnels. About a year ago, I asked one of my graduate students, Brian van Lear, to write a term paper on the use of nitrosyl azide for wind tunnels. It still looks like a pregnant idea. We are now writing a manuscript based in part on that paper.

Edward A. Fletcher
Professor of Mechanical Engineering
University of Minnesota, Minneapolis

Tea cannot improve memory

An article entitled "Natural product may be Alzheimer's therapeutic" (C&EN, Sept. 20, page 35) reported the research progress on the use of huperzine A in treatment of Alzheimer's disease. Indeed, huperzine A shows potential advantages over tacrine and physostigmine; it is longer lasting, less toxic, and more specific in its action. In clinical trials conducted in China, Alzheimer's and memory-impaired patients treated with huperzine A exhibited significant memory improvement.

However, drinking the tea of *Huperzia serrata*, a crude extract containing huperzine A, does not improve memory. The

Continued on page 79

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Chemical Capital Expenditures To Turn Up After Three-Year Decline

■ ***Hefty portion of rise will go to process improvements, expansion of existing plants in effort to reduce costs***

Marc S. Reisch,
C&EN Northeast News Bureau

Chemical companies expect that the U.S. economic recovery will finally mean improvements in sales and profit margins for them in 1994. As a result, many chemical producers plan to increase capital spending in 1994.

Total capital spending for a group of 18 chemical companies surveyed by C&EN is projected to rise in 1994 an average of 6% above that of 1993 to $6 billion, although individual companies' plans vary from no increase to a 50% increase, and few are even close to the average. In the survey, the same companies said plant and equipment spending this year declined 6% from last year to a total of $5.7 billion.

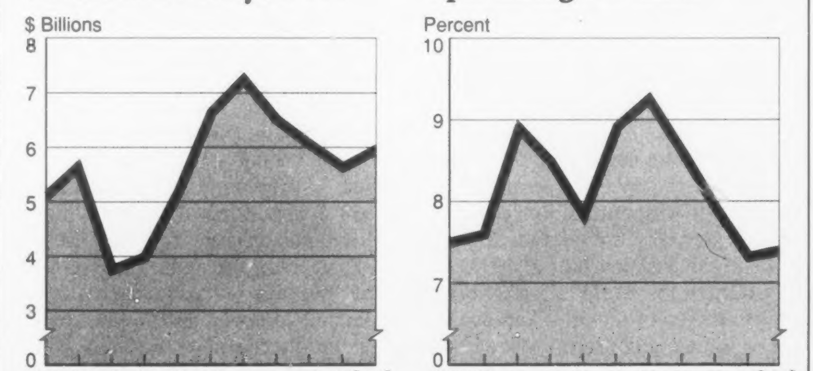
Cost control, though, is the industry byword—despite capital expenditures involving huge sums of money. Some companies will construct new plants, but the majority of chemical companies C&EN surveyed say they will continue to place major emphasis on process improvements and incremental expansions at existing plants in an effort to curb unit costs. In addition, continued expenditures on computers and operating software will allow companies to refine efforts to monitor plant processes, inventories, and customer orders, in another effort to curb costs.

Like last year, pollution abatement spending will characterize a hefty portion of capital expenditures. Although they cannot always justify such expenditures as cost-saving measures in the short term, companies must nonetheless comply with federal and state clean air and water mandates. From a legal standpoint, they must also limit their exposure to long-term pollution liabilities.

A survey of capital expenditures conducted among member companies by the Chemical Manufacturers Association (CMA) a few months ago and published this month, forecasts a 5% annual increase in chemical industry capital spending next year to $24.6 billion, based on 91 respondents. Although CMA's findings largely agree with C&EN's for 1994, the two surveys differ in their assessment of 1993 spending results. CMA estimates a 1.8% increase over 1992, based on 91 respondents, and C&EN estimates a 6% drop, based on 18 respondents. The discrepancy between the two surveys may be attributed to the timing of C&EN's survey compared with CMA's. Because C&EN conducted its survey earlier this month, companies may have a better estimate in hand for 1993 results than they did when CMA conducted its survey.

The CMA survey also found that pollution abatement spending will continue to rise. Over 16% of new capital expenditures, or nearly $4 billion went to pollution abatement control in 1993 and will continue to rise as a percentage of expenditures in 1994. These results, too, were in line with C&EN's survey.

Dow Chemical's light hydrocarbon plant under construction in Freeport, Tex., is slated to start up in first-quarter 1995.



Note: Combined data from 18 major chemical producers listed on page 12. a C&EN estimate.

Surveyed companies plan 6% capital spending jump in 1994

	1994		1993		Worldwide						
										% change	
$ Millions	Total	U.S.	Total	U.S.	1993 planned[a]	1992	1991	1990	1989	1994	1993
Betz Laboratories	$ 60	$ 42	$ 70	$ 50	$ 80	$ 74	$ 58	$ 58	$ 53	–14%	–5%
Crompton & Knowles	20	na	15	na	15	13	11	16	13	33	15
Dow Chemical	1,400	800	1,500	950	1,800	1,595	1,908	2,119	1,756	–7	–6
Ethyl	230	na	210	na	300	157	166	152	119	10	34
Ferro	65	na	53	na	60	45	39	60	50	23	18
Hercules	165	83	165	74	193	150	215	273	293	0	10
Lubrizol	140	90	125	80	na	96	82	77	65	12	30
Monsanto[b]	510	350	470	330	na	586	591	750	607	9	–20
Morton International[c]	256	222	201	176	238	200	164	111	132	27	1
3M	1,200	745	1,200	745	1,326	1,318	1,326	1,275	1,137	0	–9
Nalco	135	85	120	81	140	131	137	115	86	13	–8
Occidental Chemical	180	na	160	na	150	258	234	318	412	13	–38
Olin	150	na	140	na	155	173	177	187	142	7	–19
Petrolite[d]	30	25	20	17	na	18	22	18	19	50	11
PPG Industries	400	230	330	161	400	283	335	567	671	21	17
Praxair	300	na	275	na	315	333	417	363	243	9	–17
Rohm and Haas	380	290	375	220	300	283	265	412	385	1	33
Union Carbide[e]	425	380	300	270	360	359	400	381	483	42	–16
TOTAL	$6,046		$5,729			$6,072	$6,547	$7,252	$6,666		
ANNUAL CHANGE[f]	6%	6%	–6%	0%	9%	–7%	–10%	9%	25%		

a Earliest estimate. b Figures for 1992 and 1993 exclude Fisher Controls, sold in October 1992. c Fiscal year ends June 30. d Fiscal year ends Oct. 31. e Figures restated to 1988 to reflect spin-off of Praxair in June 1992. f Cumulative changes for companies reporting. na = not available

According to economist Alexander Paris, of investment brokerage house Barrington Research Associates, Barrington, Ill., increased capital spending next year could result, at least in part, from global pricing trends. The slow European and Japanese economies are currently hurting raw materials producers such as chemical and metal companies, but he believes that as overseas economies pick up in the second half of 1994, capital budgets could start to rise significantly. He predicts that 1995 could be a "great year," with prices up and economies percolating. Capital budgets could increase significantly again.

Raw materials producers now lag behind in capital equipment outlays compared with U.S. industry as a whole, Paris says. In the first half of 1993, all industry capital equipment outlays rose nearly 20%, and continued to outstrip the 1992 investment pace. He says that spending on computer process controls for all industry also rose 20% in the first half of 1993. And he predicts the trend to retrofit with available state-of-the-art equipment using computer process controls will continue into 1994. Respondents to C&EN's survey also detailed some planned computer-related purchases.

This year's C&EN survey differs from last year's (C&EN, Dec. 21, 1992, page 9) because of the conspicuous absence of one major spender, DuPont, and four others. Although overall trends that the survey charts remain largely the same, the order of magnitude has changed: This year's total capital expenditures for reporting companies is lower by nearly $4 billion compared with the year-earlier survey.

An important fixture of annual surveys in the past, DuPont was unable to provide any data for either 1993 or 1994. It planned to spend nearly $2.8 billion in last year's survey of projected 1993 expenditures. Another big spender—American Cyanamid—was not included in this year's table because its chemicals business, Cytec, is about to be spun off to shareholders as a separate company. Not enough data exist to include an entry for Cytec alone. Last year, American Cyanamid planned 1993 expenditures of $420 million. International Flavors & Fragrances also was unable to respond in time for the survey, and so could not be included. It planned to spend $80 million in 1993. Air Products and W. R. Grace did not supply 1994 figures. Two companies are new to this year's survey—Lubrizol and Petrolite.

Of the 18 chemical producers who reveal 1994 plans, 14 expect to increase capital spending, two plan to hold spending to this year's levels, and two plan to decrease spending. Percentagewise, Petrolite plans the largest increase—50% to $30 million, from a small base of $20 million. Expenditures include the construction of a new office building and production facilities expansions. Union Carbide plans a 42% increase to $425 million, Crompton & Knowles plans a 33% increase to $20 million, and Morton International plans a 27% increase to $256 million.

Other companies with plans for double-digit spending increases next year include Ferro, with a 23% increase to $65 million, and PPG Industries, with a 21% increase to $400 million. Nalco and Occidental Chemical both plan 13% increases to $135 million and $180 million, respectively. Lubrizol plans a 12% increase to $140 million, and Ethyl plans a 10% increase to $230 million. Ethyl plans to spin off its chemicals business to shareholders sometime early next year and supplied its spending figures on a pro forma basis. A spokesman for the company projects chemical capital spending alone for 1994 at $95 million, up 12% from this year.

Other firms planning smaller in-

European chemical giants to curb world capital spending, but boost it in U.S.

$ Millions[a]	1994		1993		% change worldwide	
	Total	U.S.	Total	U.S.	1994	1993
BASF[b]	$2,059	$ 400	$2,529	$ 460	–19%	–8%
Bayer	1,824	600	1,824	490	0	–3
Degussa[c,d]	294	75	293	69	0	–22
Hoechst[a]	1,942	560	1,942	560	0	–11
Lonza	120	30	120	20	0	–16
Rhône-Poulenc[a]	1,000	174	948	206	5	–28
TOTAL	**$7,239**	**$1,839**	**$7,656**	**$1,805**		
ANNUAL CHANGE[e]	**–5%**	**2%**	**–12%**	**19%**		

a $1.00 = 1.7 deutsche marks, $1.00 = 1.5 Swiss francs, $1.00 = 5.8 French francs. **b** U.S. data includes Canada. **c** U.S. data includes Mexico and Canada. **d** Fiscal year ends Sept. 30. **e** Cumulative change for reporting companies.

Six big European chemical companies—BASF, Bayer, Degussa, Hoechst, Lonza, and Rhône-Poulenc—forecast their capital expenditures worldwide will decline 5% in 1994 compared with spending levels in 1993, but their expenditures in the U.S. will rise 2%.

The recession still under way in Europe continues to hurt these large chemical companies, although, like their U.S. counterparts, they see a pickup in their North American business. Prospects for a recovery in Europe in 1994 are fair. So although the 18 U.S.-based companies that responded to C&EN's survey plan on average to increase their worldwide spending 6% in 1994, the European producers, with the bulk of their assets in Europe, plan a 5% drop in expenditures.

Of the six European-based producers, only one plans a significant cut in worldwide capital investments in 1994, one plans an increase, and four plan to maintain their expenditures in 1994 at the same level as in 1993. BASF plans the only cut in capital spending in 1994 compared with 1993, down 19% to a little less than $2.1 billion.

The four projecting the same global capital spending next year as this year are Bayer, which will spend $1.8 billion; Degussa, which will spend $294 million; Hoechst, which will spend $1.9 billion; and Lonza, which will spend $120 million. Only Rhône-Poulenc plans to increase its capital expenditures by 5% to $1 billion.

While these European chemical giants acknowledge a rather shaky European economic climate, as a group they recognize better immediate growth prospects in North America in 1994. Three plan to increase spending in the U.S., one plans no change, and two plan decreases. Lonza plans the largest increase, up 50%, to $30 million. The Switzerland-based company intends to expand its production capacities for hydantoin products in its Williamsport, Pa., facility. Bayer's U.S. company, Miles, plans the next largest increase, up 22% to $600 million. Degussa plans a more modest 9% increase to $75 million. Hoechst plans no increase in U.S. spending—it will spend the same $560 million on capital expenditures in 1994 as it spent in 1993.

Rhône-Poulenc plans to cut its North American expenditures 16% to $174 million. BASF plans a less severe cut in its U.S. and Canadian expenditures, down 13% to $400 million in 1994 compared with 1993.

The six Europe-based chemical companies spent 12% less worldwide in 1993 than they spent as a group in 1992. But in the U.S. market, as a group, these same six companies increased 1993 expenditures 19%. Though the recession was still quite severe in Europe during 1993, many of these chemical giants shifted capital resources to their U.S. operations, where economic recovery already had begun.

creases include Monsanto and Praxair, both of which plan to increase capital spending 9% to $510 million and $300 million, respectively. Olin plans a 7% increase to $150 million, and Rohm and Haas plans only a 1% increase to $380 million. The two companies that plan to hold 1994 spending at 1993 levels are Hercules, which plans to spend $165 million, and 3M, which forecasts spending of $1.2 billion.

However, two companies plan to decrease capital spending next year. Betz Laboratories plans a 14% reduction to $60 million, and Dow Chemical plans a 7% cut to $1.4 billion.

For the group of 18 companies surveyed, C&EN estimates that combined capital spending as a percentage of sales will weigh in at 7.4% for 1994. That forecast is down from peak spending levels as a percentage of sales of 9.3% for reporting companies in 1990. The 1994 prediction is based on the assumption that capital spending will increase 6% for reporting companies. It also assumes a sales increase for the group of 4.5%.

For 1993, C&EN estimates that companies surveyed spent the same 7.3% of sales on plant improvements and equipment purchases as they may spend in 1994. That figure is based on the assumption that sales grew at only 1.5% for the group surveyed in 1993. It also accepts the survey's results showing that capital expenditures for the group of 18 companies declined 6% in 1993 compared with 1992.

This year's survey also predicts 1994 capital spending in the U.S. will increase at the same 6% pace as spending by responding companies worldwide. Nine companies plan to increase domestic spending, one plans to continue spending at the same pace as it did in 1993, and two plan spending decreases. Petrolite plans the largest spending increase, up 47% to $25 million on a small base, while PPG plans a sizable 43% increase to $230 million, and Union Carbide plans a 41% increase to $380 million.

Also planning large spending increases are Rohm and Haas, up 32% to $290 million; Morton International, up 26% to $222 million; and Lubrizol, up 13% to $90 million. Hercules plans a 12% increase to $83 million. Planning single-digit increases are Monsanto, up 6% to $350 million, and Nalco, up 5% to $85 million. Only 3M plans no spending increase, and will spend the same $745 million in 1994 as it did in 1993. The two companies that plan domestic decreases are Betz Laboratories, which will spend $42 million, down 16%, and Dow Chemical, which will spend $800 million, also down 16% from 1993. ☐

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CHEMICAL & ENGINEERING NEWS

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JANUARY 3, 1994

NEWS OF THE WEEK

- A primitive DNA "retroelement" found and characterized by Ohio State researchers may be the ancestor of modern DNA-based organisms. **Page 5**
- U.S.-Russia cooperation in science and technology has received another boost with the recent visit to Moscow of a high-level group led by Vice President Al Gore. **Page 6**
- American Cyanamid has completed the spin-off of its Cytec Industries subsidiary, which encompasses essentially all of Cyanamid's specialty and commodity chemical operations. **Page 6**
- University of California, San Diego, scientists have developed a method for dendritic growth of conducting polymers between platinum wires. **Page 7**
- Crypt of St. Mark's Basilica in Venice has been restored, largely through materials and financial help from France's Rhône-Poulenc, after being walled up for 400 years because of flooding. **Page 8**
- DuPont will continue to produce chlorofluorocarbons through 1995 at the request of EPA, even though the company had planned to halt their production by the end of this year. **Page 8**

COVER: Photo by George W. Baker, Christmas City Photography Studio

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BUSINESS

Massive global overcapacity continues to dampen the outlook for titanium dioxide, although the market for the ubiquitous white pigment probably will grow a little this year. **Page 14**

Dow Plastics sees moderate growth in sales this year, a bit ahead of that for the overall plastics industry in the U.S. **Page 15**

How to succeed at joint ventures in Eastern Europe is the subject of a handbook published in London and sponsored by the Confederation of British Industry. **Page 16**

GOVERNMENT

NIH director Harold E. Varmus talks about the importance of basic research, the selection process for funding of research proposals, and the external political climate. **Page 18**

SCIENCE/TECHNOLOGY

Design and synthesis of a hollow, spherical dimeric complex that self-assembles via hydrogen bonding marks the birth of a new family of supramolecular complexes. **Page 23**

Chemists have produced "sea urchins"—structures in which single-layer carbon nanotubes radiate in three dimensions from gadolinium-carbon cores. **Page 24**

Carlyle Storm replaces Alexander Cruickshank as director of the Gordon Research Conferences and faces the challenge of the declining proportion of industrial scientist participants. **Page 25**

BOOKS

Compass and gyroscope are metaphors for science and democracy in book that broaches the subject of sustainable development; author asks pointed questions, but omits crucial details. **Page 26**

TRADE AGREEMENT

Chemical industry still has concerns over the recent Uruguay round trade pact, particularly over the small number of countries participating in the chemical tariff cuts. Page 11

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LETTERS

Space station booster

This letter is in response to the one written by Robert J. Good, "Space station turkey" (C&EN, Nov. 29, page 4). I have been saying this so often that I sound like a broken record, but when I hear shortsighted opinions like the one expressed by Good, I cannot help but reply.

This country is in an economic crisis. Every week we read of another major corporation restructuring or downsizing and eliminating people including scientists, engineers, managers, and skilled tradespeople. The job market for recent college graduates (including chemists) is the worst that it has been in recent years. Furthermore, industry does not intend to rehire people when the economy improves. Industry has found that with automation it can produce the same amount of product with fewer workers, and it will do so. This is called increasing productivity.

This country needs the space station. It is necessary for the future of the space program, including the development and exploration of the Moon. Space is the big industry that will supply jobs for the future generation of Americans. The time to act is now. The Russians are ready to cooperate and participate (C&EN, Nov. 22, page 29). We should not let this opportunity slip by. This is the dawn of the 21st century. Space is our future. All scientists should support it.

Donald L. Miller
Midland, Mich.

Rockne was no chemist

In your Sept. 6 issue (page 35), you have a meeting brief entitled, "Famous football coach [Knute Rockne] also had chemistry career," and you quote a paper by James F. O'Brien as your source.

I recently wrote a book, "Shake Down the Thunder: The Creation of Notre Dame Football" (Henry Holt & Co., New York, N.Y.) based in large part on Rockne's daily correspondence, which I found, by chance, in a subbasement of the Notre Dame library. In that book, I debunk the myth—promulgated by the Hollywood film "Knute Rockne—All-American"—that the coach could have been a great chemist. In fact, Rockne briefly taught high school chemistry in Notre Dame's prep school because the administrators of the time did not believe that he had enough to do coaching football and track—his main preoccupations. Then, because of the shortage of teachers during World War I, he briefly taught in the university division.

Rockne's name was kept in the university bulletin as a chemistry teacher until 1922 because, through vanity and his clout as a football coach, he insisted on it. In addition, the claim that, in the 1920s, Columbia University and Ohio State University offered him positions in chemistry is based on a number of casual biographies and articles about the coach by journalists who offered no footnotes or factual evidence for these or any other assertions in their works. However, in my book, I carefully document the Rockne-as-chemist myth, and I base my refutations on the coach's private papers as well as the papers of the Notre Dame administrators of the time.

Knute Rockne always wanted to be a football coach and, in many ways, was the first big-time college coach. His connection to chemistry was about as close, to quote Thorstein Veblen, as bullfighting is to agriculture.

Murray Sperber
Associate Professor of English
and American Studies,
Indiana University, Bloomington

Low voter turnout

As an emeritus member of ACS, I was appalled, shocked, and dismayed by the low voter turnout in the ACS presidential election (C&EN, Nov. 22, page 6). Of 145,000 ACS members, only 26,323 (less than 19%) took the time to vote for the leader who will direct our society for the coming years.

Don't you members have enough interest to take a few minutes to review the biographies and candidates' statements and then spend 29 cents for a stamp to make yourself heard in your own society? For the price, you couldn't get a better bargain.

Even though retired as a working chemist for the past 10 years, I still believe that we, as members, should all exercise our franchise.

Bernard M. Balnk
Flushing, N.Y.

1994 dues bill

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Global overcapacity holds back titanium dioxide

After a tumultuous 18 months beginning in the second half of 1992, the global market for titanium dioxide (TiO_2) has calmed down some, and the outlook is for a little growth in 1994. That is the year-end assessment of the market for the ubiquitous white pigment, according to Dennis H. Reilley, vice president and general manager for white pigments at DuPont.

Speaking at a briefing last month in London, Reilley pointed out that the major problem for the industry is massive global overcapacity. Current capacity for TiO_2 is about 3.5 million metric tons per year, whereas annual demand is about 3.0 million metric tons. Demand was up 0.5% in 1993 from the previous year.

Prices are so low that, by DuPont's analysis, roughly half the capacity around the world is being operated at a loss. Prices are at too low a level to justify investment, Reilley said. And although new investment is not needed now, he said, when the recession that has been hampering world economies does end and growth in demand for TiO_2 picks up, "the next shortage is not a question of 'if,' but 'when.'

"The difficult part to predict is when pigment demand will pick up," he pointed out. "When you come out of recession, there is strong demand—as much as 10%—but more generally 6 to 7% per year for a couple of years. That is consistent with history. If 1994 or 1995 is the beginning of that upturn, we will see supply and demand balance back in by about 1996 or 1997." And, by implication from DuPont's figures, if demand continues to grow—while some existing capacity is shut down and no investment replaces it—the industry will see shortages by the end of the decade.

Almost all of the new capacity for the pigment brought on stream in the past two years has used a chloride process; all of the capacity that was shut down has been sulfate process. The result has been a net reduction in capacity worldwide. And, said Reilley, "nothing indicates that this trend is going to stop."

DuPont claims the largest share of the world's TiO_2 market, with 24% of capacity. According to DuPont's estimates, Tioxide, part of ICI (U.K.), is second largest with 14%; followed by SCM Industrial (U.S.), part of Hanson plc, with 12%; Kronos (U.S.) at 11%; Kemira (Finland) with 7%; and Kerr-McGee (U.S.) and Ishihara (Japan), each with 5%.

DuPont does not produce in Europe, although it would like to. Last summer Kemira beat DuPont to the purchase of a chloride process plant in the Netherlands. To have capacity in Europe just to have capacity there, said DuPont officials, "is not in itself enough." But there also is the undeniable fact that five of the top 10 paint companies in the world are European based—a marketing consideration that has not been lost on DuPont.

On the other hand, the company is a major factor in the Asia-Pacific region, with what it says is an 18% share of the market, second only to Ishihara, the predominant supplier in Japan. In April, DuPont will start up in Taiwan a 60,000-metric-ton-per-year chloride-process plant. However, the company is not worried about oversupply in the region. "There is plenty of demand there," Reilley said. "We can rearrange our supply lines a bit. It is a high growth region."

The new unit in Taiwan is the last new plant construction project on the books. "Nobody sneaks up on you in this business—it's a five-year [time frame] from design to startup," Reilley said. A producer of the pigment could probably expand a plant in only about one or two years, he conceded, but "we probably won't see it: The problems have just been too rugged for the industry."

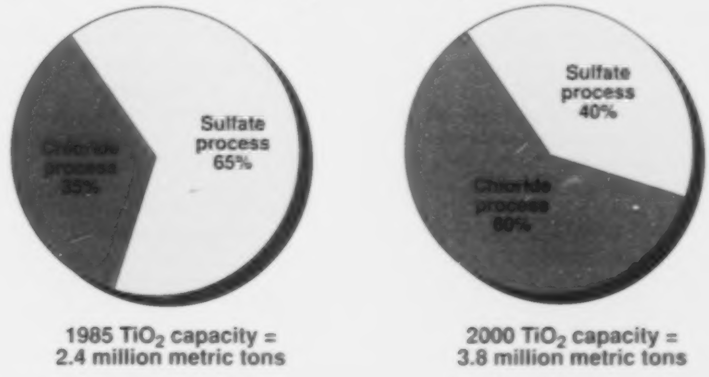
Patricia Layman

TiO_2 capacity shutdowns rise following 1991, 1992 additions

Thousands of metric tons	New capacity	Shutdowns
1991		
Savannah, Ga.	55[a]	
Bunbury, Australia	70[a]	35[b]
Kwinana, Australia	55[a]	
Burnie, Australia		20[b]
Stallingborough, U.K.		20[b]
NET CHANGE	+105	
1992		
De Lisle, Miss.	90[a]	
Ashtabula, Ohio	55[a]	
Lake Charles, La.	80[a]	
Malaysia	50[b]	
Saudi Arabia	50[a]	
Tracy, Quebec, Canada		25[b]
Varennes, Quebec, Canada		20[b]
NET CHANGE	+280	
1993		
Tracy, Quebec, Canada		20[b]
Grimsby, U.K.		35[b]
Antwerp, Belgium		15[b]
Furukawa, Japan		10[b]
NET CHANGE	–80	
1994–95[c]		
Taiwan	60[a]	
Europe		80[b]
Asia-Pacific		75[b]
NET CHANGE	–95	

a Chloride process. **b** Sulfate process. **c** Planned.
Source: DuPont

Global trend to chloride-process TiO_2 continues



1985 TiO_2 capacity = 2.4 million metric tons

2000 TiO_2 capacity = 3.8 million metric tons

Source: DuPont

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CHEMICAL & ENGINEERING NEWS

C&EN

JANUARY 17, 1994

PATENT OFFICE CHIEF AIMS TO REVITALIZE ENTIRE PATENT SYSTEM PAGE 13

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CHEMICAL & ENGINEERING NEWS

C&EN

JANUARY 17, 1994

NEWS OF THE WEEK

- EPA issues proposed rule that would almost double the number of chemicals—from 320 to 633—that U.S. industrial companies must monitor for the Toxics Release Inventory. **Page 4**
- New technique for making large synthetic proteins of unprecedented size may be applicable to development of new vaccines, biosensors, and peptide libraries. **Page 5**
- Researchers find superconductivity for the first time in quaternary intermetallic compounds—specifically, yttrium-nickel boride carbides (Y-Ni-B-C) and yttrium-palladium boride carbide (Y-Pd-B-C). **Page 5**
- Business community and Administration, working on Superfund renewal, are expected to propose hybrid liability schemes to try to satisfy concerns of both industry and insurance companies. **Page 6**
- Slower growth in drug industry R&D investment in 1994—the lowest rate of increase in 17 years—is projected by the Pharmaceutical Manufacturers Association. **Page 7**

COVER: Photo courtesy of NASA

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BUSINESS

Stock prices rose for many chemical firms last year, largely because of improved earnings performance and cost cutting together with prospects for future earnings growth. **Page 10**

GOVERNMENT

Bruce A. Lehman, new Commissioner of Patents & Trademarks, discusses the need for stronger, more defensible patents, his goals for the reform of the U.S. patent system, and international harmonization of the patent process. **Page 13**

SCIENCE/TECHNOLOGY

NASA hails the success of space shuttle *Endeavour*'s mission to repair and service the Hubble Space Telescope as the space agency plans eight shuttle flights in 1994. **Page 22**

ACS NEWS

ACS's Education Division launches teacher training program for fourth- through eighth-grade science teachers as part of the NSF-funded Operation Chemistry initiative. **Page 25**

Official reports of committees that met during the ACS Board meeting in Columbus in December are highlighted. **Page 25**

COVER STORY

A new generation of explosives and propellants for military and space applications is being developed by teams of chemists in industrial and government labs. Page 18

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LETTERS

Economic status of chemists

Many thanks to Attila Pavlath for his comment, "Economic Status of Chemists" (C&EN, Dec. 20, 1993, page 45). This topic has been debated for many years, especially during those economic times when massive layoffs and early retirements have occurred.

During the past several years, the American Chemical Society has focused on another important topic, National Chemistry Week and educating the general public about chemistry. I think these efforts have been well received, and we are all proud of our efforts here and should continue to support these programs in the future.

Now, however, I believe ACS should focus on the economic status of chemists as its number-one objective for 1994 and beyond—until some solutions have been worked out. At least, as Pavlath says, let's get started in 1994 by addressing the problem. ACS members and local sections should make their views known to the board of directors on this very important subject.

R. W. Johnson
Savannah, Ga.

Attila Pavlath presented several suggestions for improving the economic status of chemists, namely some sort of certification or licensing, immigration control, and continuing education. While these are all worthy of consideration, I believe that Pavlath omitted another very useful avenue toward expanding job opportunities for chemists; that is, broadening the basic education of chemists.

When I received my undergraduate and graduate degrees in chemistry in the 1950s, laboratory jobs were plentiful for new chemists. Back then, students could fill their schedules with their main interest—chemistry and science courses. Times have changed, but curricula seem not to be keeping pace with changing educational needs and job opportunities.

I believe that if aspiring chemists would broaden their backgrounds, they would find ample job opportunities even in today's tight job market. One example, speaking from personal experience, is the field of environmental health and safety (EHS), where a chemical background is clearly an asset, if not a must. Courses in ecology, environmental issues, pollution control, management of hazardous materials, and hazardous waste would nicely supplement a traditional chemistry curriculum and prepare a student for EHS jobs in industry and government.

Similarly, courses in education could prepare one for a teaching career in secondary or primary education, where a background in the discipline of chemistry would be useful irrespective of the subject taught. Courses in communications, public speaking, technical writing, and computer skills would also offer expanded job opportunities for chemists.

Job opportunities do exist for chemistry majors if they are prepared for and willing to look beyond the laboratory. Perhaps it's time to rethink what a chemist is, and of what a chemist's education should consist.

W. J. Vullo
Environmental Manager
General Electric Co.
Burnt Hills, N.Y.

Publicity stunt

My letter concerns the News of the Week item "Energy Department and auto firms plan joint R&D" (C&EN, Dec. 13, 1993, page 9). In the story, Ford was represented by its vice president for technical affairs; General Motors and Chrysler sent their top public relations people. Of course, "technical affairs" may be an euphemism for public relations at Ford.

The only way higher efficiency can be achieved with the large engines now affected by the benevolent automobile industry is by loading the systems with even more complicated, sophisticated electronic devices to manipulate the combustion process, than are now available. Such elegant exercises as "joint R&D" serve public relations only.

We must imitate the rest of the world by taxing motor fuel to a level that will impel the populace toward small engines. Thus, anything above 2-L displacement is redundant. Since 1974, the largest engine I have driven is in my present car (1.6 L). I get more than 40 miles per gal on the

Correction

- Jan. 3, page 5: The paper on retroelement genetics appeared in *Cell*, **75**, 1071 (1993).

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Chemical Company Stock Prices Posted Strong Growth Last Year

■ ***Stocks of most firms reflected improving finances for industry; biotechnology stocks hit high at start of 1993***

William J. Storck,
C&EN Northeast News Bureau

Last year was one of slightly improving finances for the chemical industry as earnings, profitability, and other fundamentals slowly increased from the depths of the recession. This increase was not lost on investors who drove many chemical stocks upward.

The main stock market action came late in the year as investors seemed finally to decide the recovery, no matter how slow, was real. The result was record highs set day-by-day by the Dow Jones industrial average. As the Dow Jones average was setting new highs, so was C&EN's market value index of seven major chemical companies, which charts the stock market prices of American Cyanamid, Dow Chemical, W. R. Grace, Hercules, Monsanto, Rohm and Haas, and Union Carbide.

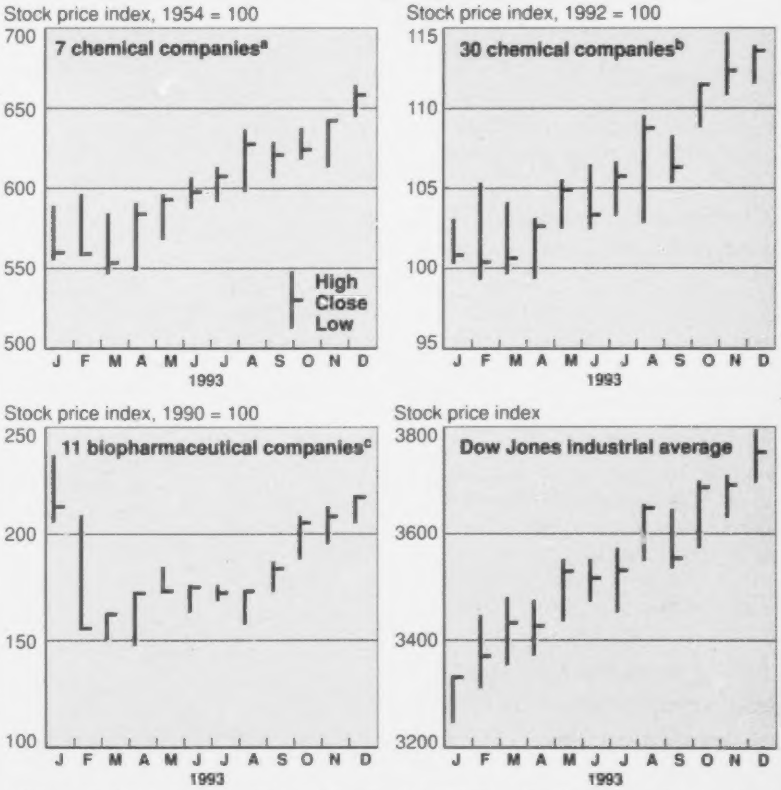
For the Dow Jones average, it was a year of progression from low to high. Granted, there were the natural fluctuations in the index, but the yearly low of 3242 came in January and the high of 3794 came in December. By year's end, the Dow Jones average, at 3754, was almost 14% higher than at the beginning of the year.

For chemical stocks, the picture was much the same. The year began on a fairly good note, with C&EN's seven-company index finishing 1992 at 587.8 (1954 = 100). In March, the index dropped about 6% to a yearly low of 545.8, but from then on it showed generally steady growth until it hit a yearly high of 662.6 in December, then settled back slightly to end the year at 658.5, 21% above the 12-month low and 12% ahead of the start of the year.

C&EN's broader 30-chemical company index followed much the same pattern as that of the seven-company index, except that the lows and highs each occurred a month earlier than those for the seven-company index and the growth was not as dramatic. The 30-company index, which ended 1992 at 103.7 (1992 = 100), declined 4% to its yearly low of 99.1 in February, then began to rise until it hit its yearly high of 114.7 in November, 16% higher than its yearly low. Like the other chemical index, it then settled back to end the year at 113.3, almost 15% ahead of the 12-month low and slightly more than 9% ahead of the index at the beginning of the year.

C&EN's biotechnology stock index behaved differently—the high came at the beginning of the year, rather than at the end. This index of the stock value of 11 biopharmaceutical companies reached its 1993 high of 237 (1990 = 100) in January. It then slipped to a low of 148 in April and started to build once again to

Stock market indexes rose rapidly toward end of 1993



[a] Based on stock prices for American Cyanamid, Dow Chemical, W. R. Grace, Hercules, Monsanto, Rohm and Haas, and Union Carbide. [b] Based on stock prices for 30 chemical companies listed in table on page 11. [c] Based on stock prices for Amgen, Applied Bioscience, Biogen, Centocor, Chiron, Cytogen, Genentech, Genetics Institute, Immunex, Repligen, and Xoma.

Some chemical stock prices chalked up large gains in 1993

	1993 stock price			% change 1993	Price-earnings ratio[a]	Dividend yield, % of price
	High	Low	Close			
Air Products	$ 48	$37⅞	$ 44¼	–5.3%	25	2.1%
American Cyanamid	58	47	50¼	–12.8	def	3.5
Arco Chemical	47⅛	39⅜	43¼	–1.1	22	5.8
Betz Laboratories	62½	41⅛	43⅞	–29.1	18	3.2
Cabot	58⅜	37¼	53⅞	24.2	30	1.9
Crompton & Knowles	25½	17⅝	22	–1.1	23	1.8
Dow Chemical	61⅞	49½	56¾	–0.9	36	4.6
Ethyl	30⅝	16⅞	17½	–38.9	8	3.4
First Mississippi	13¼	8½	13⅛	41.9	def	2.3
H. B. Fuller	42¼	31¼	36	–11.1	17	1.6
Georgia Gulf	23¾	16¾	22⅜	0	23	nd
BF Goodrich	54	39¾	40¼	–17.6	29	5.5
W. R. Grace	41¼	34⅝	40⅝	0.9	def	3.4
Great Lakes Chemical	83½	64½	74⅝	7.8	13	0.5
Hercules	113½	64¼	113½	78.7	26	2.0
IMC Fertilizer	46⅝	25⅛	45⅜	6.5	def	nd
Imcera	37¼	23	33⅝	–0.4	def	1.5
International Flavors	118⅝	99½	113¾	4.6	23	2.8
Loctite	45⅝	34⅞	36¾	–19.0	18	2.2
Lubrizol	36¼	26¾	34⅛	25.2	35	2.6
Monsanto	74¾	49¾	73⅜	27.3	15	3.2
Morton International	99⅝	58	93½	53.6	34	1.2
Nalco Chemical	37¾	31½	37½	8.3	19	2.4
Olin	50¼	40⅛	49⅜	7.9	40	4.5
Petrolite	40¼	27¾	35	22.8	19	3.2
Praxair	18⅝	14⅛	16⅝	–0.1	24	1.5
Rohm and Haas	61⅜	47⅞	59½	11.2	48	2.4
Stepan	37⅝	25½	28⅛	–15.4	15	3.0
Union Carbide	22¾	16⅛	22⅜	34.6	26	3.4
Witco	31⅞	24¼	31⅞	26.9	34	3.1

[a] Includes extraordinary and nonrecurring items. **def** = deficit. **nd** = no dividend.

end the year at 218, up 47% from the 1993 low and 12% below the opening mark for the year.

While C&EN's chemical indexes (as opposed to the biopharmaceutical index) were moving up in 1993, other indexes of chemical stock performance showed less impressive gains. The Dow Jones industry group index for chemicals increased 7% for the year, with the commodity chemical index moving up 9% and the specialty chemical index growing less than 4%. The differences could arise because the Dow Jones groups include companies with a greater percentage of their business in nonchemical areas. Also, the Dow Jones averages are based solely on stock price, whereas C&EN's indexes are based on market value (stock price times the number of shares outstanding) of the companies.

The individual companies incorporated in C&EN's chemical indexes had mixed stock performance during the year. On the seven-company index, five companies posted increases for the year, with the other two posting declines. However, for the 30-company index, the stock performance of the firms was split much more evenly with 16 advances, 13 declines, and one company unchanged.

By far the biggest advance, and one that did the most to help boost both indexes, was registered by Hercules, whose stock price improved 79% during the year to finish at $113½ per share. This also was the company's highest stock price of the year.

Other companies posting good gains for 1993 include Morton International, up 54% to $93½; First Mississippi, up 42% to $13⅛; Union Carbide, up 35% to $22⅜; Monsanto, up 27% to $73⅜; and Lubrizol, up 25% to $34⅛.

Earnings performance and cost cutting plus expectations of future earnings growth seem to have driven the stock price of these good performers this year. With the exception of First Mississippi, all of these companies had good earnings growth through 1993. For instance, Hercules' earnings through the first nine months of 1993 were up 24% from the same period a year earlier and rose 27% in both the second and third quarters over the comparable quarters in 1992.

Monsanto's earnings for the first nine months were down slightly from the year-earlier period, but third quarter earnings from operations more than doubled from the same period in 1992. Union Carbide saw 73% growth in profits in the third quarter and 21% for the first nine months. And Morton International's earnings increased 23% in the third quarter and were up 19% through the nine-month period. First Mississippi registered a 54% decline in third-quarter earnings, which caused a 50% drop for the nine months. However, the outlook for growth in fertilizer use plus cost cutting at the company has helped improve the stock price.

The outlook for expanding markets is also helping Union Carbide, where analysts see improvement in sales of polyethylene, one of the company's major products. Optimism about a reorganization at the company also is helping. And at Monsanto, cost reduction, increased sales of chemicals and pharmaceuticals, and expectations for increased demand for agricultural chemicals is helping to push the stock price slightly above some analysts' expectations.

On the down side, Ethyl Corp.'s stock price slid 39% during the year to finish at $17½ per share. Other companies whose stock prices declined include Betz Laboratories, down 29% to $43⅞; Loctite, down 19% to $36¾; BF Goodrich, down 18% to $40¼; and Stepan, down 15% to $28⅛.

The good news coming out of all of the indexes is that investors are betting on the health of the chemical industry. It has long been accepted that the market is a leading indicator of the economy and that the industry segments of the stock market are pretty fair predictors of the state of those industries about three to six months into the future. If this holds, and there is no reason to doubt that it will, then the chemical industry likely will be seeing a fairly good first half this year compared with the same period of 1993. ☐

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CHEMICAL & ENGINEERING NEWS

C&EN

JANUARY 24, 1994

CHEMICAL INDUSTRY R&D SPENDING TO DECLINE SLIGHTLY IN 1994 PAGE 15

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SOAPS & DETERGENTS

Suppliers help soap formulators meet demand
of a complex, competitive marketplace
Page 34

CHEMICAL & ENGINEERING NEWS

C&EN

JANUARY 24, 1994

NEWS OF THE WEEK

- Refinements to EPA's conservative method for estimating health risks posed by pollutants are recommended in report by the National Research Council. **Page 6**
- Solar device using thin film amorphous silicon developed in joint government-industry project could lead to solar energy generation at half the current cost. **Page 7**
- The earthquake in Southern California, despite its severity, did little damage to most universities and other research institutions in the Los Angeles area. **Page 8**
- ACS, other U.S. scientific societies are protesting Russian plans to conduct a closed trial of chemist Vil Mirzayanov for allegedly divulging state secrets about Russian chemical weapons work. **Page 8**
- Eli Lilly will concentrate on its core pharmaceuticals operation and divest nine medical device and diagnostics businesses accounting for about 19% of its sales. **Page 9**

COVER: Industrial-grade washing machines in hotel laundry. Photo courtesy of PQ Corp.

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BUSINESS

Major chemical firms will spend slightly less on R&D this year and are reexamining their approach to research expenditures and management, largely because of slow economic growth. **Page 15**

GOVERNMENT

EPA is planning to integrate environmental equity into all of its policies in recognition that some minority and poor communities have been overly burdened by toxic pollution. **Page 22**

SCIENCE/TECHNOLOGY

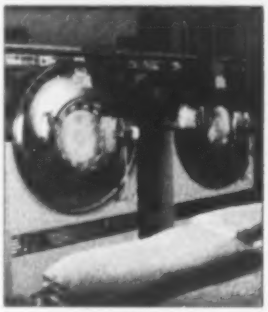
NSF's industry-university cooperative research centers program, which develops and transfers industrially relevant technologies from the university into practice, marks 20th birthday. **Page 25**

Failure of the Mars Observer spacecraft last August was due to a highly energetic chemical reaction that ruptured propulsion system tubing, concludes an independent investigative board. **Page 30**

MEETINGS

Program for the Division of Polymeric Materials: Science & Engineering conference on polymer blends and alloys features 20 presentations in five sessions. **Page 67**

PRODUCT REPORT



Soap and detergent manufacturers rely increasingly on suppliers to keep up with reformulations, motivated by consumers who want products that are more economical and have increased cleaning power as well as reduced environmental effects. Page 34

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LETTERS

Industry-PTS communication

I am writing you about Lois Ember's interesting article, "Chemical Industry Offers Its Expertise for Implementing Chemical Arms Pact" (C&EN, Nov. 1, 1993, page 21).

In that article, Ember highlights Sylwin Gizowski's recommendation about the importance of "establishing direct and informal contact between industry associations and the Provisional Technical Secretariat (PTS)." In that regard, it would perhaps be useful to make some comments.

Since the second quarter of 1993, PTS has started establishing contacts with chemical industries to facilitate the implementation of the Chemical Weapons Convention (CWC) and to foster industry interest on all issues related to the convention. For that purpose, PTS has developed procedures for exchanging information with specific United Nations organizations, as well as with a number of industry associations, when industry-related CWC subjects are raised.

Other procedures have also been explored and introduced. For example, a seminar on national trial inspections was held in The Hague in early October 1993; PTS staff members have participated in regional industry events; and the Preparatory Commission's expert groups have met with industry representatives. The first meeting with the industry representatives was fully reported on in Ember's article. PTS is studying the possibility of organizing additional meetings with industry representatives in 1994.

On the other hand, the industries of each country should discuss their CWC-related concerns with their respective governments. Such discussions would enable their governmental representatives in the Preparatory Commission to reflect the industry's views and act as liaison between PTS and their national chemical industries as effectively as possible.

Moreover, PTS is also acting to develop and intensify its contacts with industry. In this regard, the industry relations branch of the External Relations Division has the responsibility for establishing contact with chemical industry associations and companies and providing updated information and advice on any concerns that may arise out of the implementation of the convention. Chemical industries can always get in touch with this branch to communicate their views and concerns or to request additional information.

Raul Carlos Fernandez
Head, Industry Relations Branch
Preparatory Commission for the
Organization for the Prohibition
of Chemical Weapons
Provisional Technical Secretariat
The Hague

Correction

- Jan. 17, page 25. The telephone number to receive information about Operation Chemistry teacher training workshops is (202) 872-6366.

Intellectual property issues

Ann Thayer's article on Dow Plastics (C&EN, Jan. 3, page 15) concludes with an unfortunate bit of misinformation. Thayer refers to a U.S. patent issued on Dec. 21, 1993, and states that Dow "was awarded a similar patent from the World Patent Office in April." The World Intellectual Property Organization (WIPO, there is no World Patent Office) did indeed publish an international patent application on this subject matter during April, but WIPO does not issue patents. Rather, it provides, under the Patent Cooperation Treaty (PCT), a means by which an individual or corporate inventor can file a single patent application, which undergoes a unified international search in any of several patent offices, after which it is sent to the patent offices of designated individual countries and regional authorities (for example, the European Patent Office) for consideration under the laws of those countries and authorities.

This mechanism can simplify patenting procedures by replacing the traditional system under which separate applications must be filed in each office of interest, with a search carried out in each. But WIPO awards nothing. It merely publishes PCT applications, which may subsequently become patents in one or more jurisdictions, but which may never proceed beyond the level of published application.

Stuart M. Kaback
Cranford, N.J.

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Chemical Industry R&D Spending To Fall Slightly in 1994

■ ***Economic pressures are causing major chemical companies to rethink strategies for research spending, management***

Ann M. Thayer,
C&EN Northeast News Bureau

Research and development, like so many other parts of industry, is experiencing the effects of slow economic growth. Downsizing, shifting focuses, and reexamined management approaches are all part of the R&D picture today.

R&D spending by 24 major chemical producers is estimated to fall an average of 1.4% in 1994, based on data recently collected by C&EN. This decrease is in contrast to an increase forecast by a major chemical industry trade group, but in line with more conservative views held by industry analysts and a survey of company R&D representatives. Cost containment measures, competitive pressures, and the lingering effects of the recession are leading companies to rethink not just how much, but also how, money is being spent on R&D.

The forecast decrease in spending in C&EN's survey for 1994 follows a year in which R&D spending slipped nearly 2%, despite more optimistic expectations a year ago. Total spending for the group of 24 companies surveyed is expected to reach $4.68 billion in 1994, down from $4.74 billion in 1993. In the past several years, the largest increases in R&D spending occurred between 1988 and 1990, when spending grew 8 to 10% per year. However, with a recession taking hold, R&D spending fell in 1991 and has not really recovered.

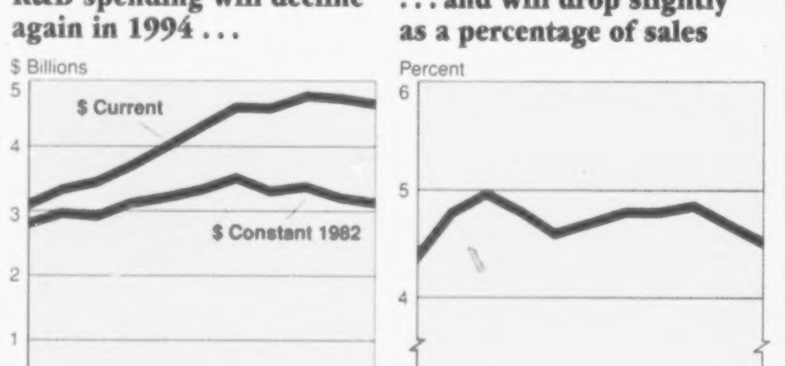
For 1993, a comparison of planned spending and actual spending shows that companies surveyed by C&EN ended up cutting back throughout the year. Planned 1993 spending for the 14 companies that provided estimates totaled $3.75 billion. Actual spending reached only $3.65 billion for the year, a decrease of nearly 3%.

Industrial R&D spending varies significantly among different sectors, and the chemical industry falls somewhere in the middle. More mature industries—such as basic metals and chemicals—don't spend a great deal on R&D in the first place, explains Jules J. Duga, senior R&D policy analyst and lead author of Columbus, Ohio-based Battelle's annual R&D spending forecast, which is expected to come out next month. At the extremes, the petroleum industry spends only about 1% of sales on R&D, whereas the more high-tech areas of pharmaceuticals, telecommunications, transportation, and electronics spend as much as 15% of sales.

Battelle forecasts total U.S. R&D spending for 1994 to reach $165 billion, a 2.4% increase over estimates for 1993. Industry will account for nearly 52% of this spending in 1994, rising only 1.6% to $85 billion. However, about 70%, or $115 billion, of total R&D dollars will be spent on research conducted by industry. About 72% of these funds will come from industry itself, with the remaining 28% from the federal government. Industry also will spend about $2.4 billion on R&D at universities and nonprofit organizations, a 6.2% increase over 1993.

In terms of constant dollars, R&D expenditures in 1994 will remain essentially flat relative to 1993, according to Battelle. Recession and other economic pressures have been major contributors to keeping spending down. "The first expenses to get cut are those that are viewed as nonrevenue producing, and, unfortunately, R&D is viewed by most people as being nonrevenue producing—that is, not producing revenue by the end of the next quarter," says Duga.

However, Duga predicts that R&D spending will start to pick up again around mid-decade. A slowdown in industrial profitability and growth, irrespective of what Duga calls the "paper" profit increases that are essentially the result of company reorganizations, has contributed to a Slinky spring toy effect on R&D spending. After recovery begins within the industry and profitability starts going


R&D spending will decline again in 1994 . . .

. . . and will drop slightly as a percentage of sales

Note: For 24 chemical companies listed on page 16
Sources: C&EN surveys and estimates. Battelle. National Science Foundation

Chemical companies surveyed show diverse R&D spending plans for 1994

$ Millions	Planned 1994	Actual 1993	Planned 1993	1992	1991	1990	1989	1988	Change from prior year		R&D spending as % sales	
									1994	1993	1993	1992
Air Products & Chemicals[a]	$ 94	$ 92	$ 93	$ 85	$ 80	$ 72	$ 71	$ 72	2.2%	8.2%	2.8%	2.6%
Arco Chemical	75	72	65	67	64	59	52	39	4.2	7.5	2.2	2.2
Crompton & Knowles	10	10	na	10	10	8	8	6	0.0	0.0	1.8	1.9
Dow Chemical	1,200	1,270	1,320	1,289	1,159	1,136	873	772	–5.5	–1.5	6.6	6.8
DuPont[b]	1,100	1,100	1,198	1,217	1,224	1,381	1,327	1,255	0	–9.6	5.0	5.6
Eastman Chemical[c,d]	174	166	na	162	154	148	na	na	4.8	2.5	4.3	4.3
Ethyl[e]	130	124	80	73	69	65	61	59	4.8	69.9	4.1	2.5
First Mississippi[f]	6	5	na	4	4	4	4	4	20.0	25.0	0.9	0.8
FMC	165	147	150	145	135	158	150	144	12.2	1.4	3.6	3.6
H. B. Fuller[g,h]	22	21	na	20	17	16	16	14	4.5	4.3	2.2	2.1
Great Lakes Chemical[d]	48	46	na	47	39	29	31	28	4.5	–3.1	3.0	3.1
Hercules	67	70	70	70	86	92	79	74	–4.3	0	2.4	2.4
Imcera[f]	100	95	na	91	81	76	65	65	5.3	4.4	5.5	5.3
Loctite[h]	27	27	na	26	22	19	17	15	0	3.8	4.4	4.3
Lubrizol[i]	88	88	88	91	80	74	70	65	0	–3.3	5.6	5.9
Monsanto[j]	580	620	na	651	610	595	581	556	–6.5	–4.8	7.9	8.4
Morton International[f]	73	69	67	61	59	48	38	35	5.8	13.1	3.2	2.8
Nalco Chemical	54	51	na	48	47	45	41	37	5.9	6.3	3.6	3.5
Olin	40	40	35	39	41	66	66	58	0	2.6	1.7	1.6
Petrolite[k]	14	14	13	12	11	12	12	12	0	16.7	4.3	3.8
PPG Industries	221	219	215	203	220	236	249	239	0.9	7.9	3.7	3.5
Praxair[l]	53	54	na	60	58	58	54	49	–1.9	–10.0	2.0	2.3
Rohm and Haas	207	205	210	199	183	178	175	156	1.0	3.0	6.6	6.5
Union Carbide[m]	129	140	150	155	157	157	143	126	–7.9	–9.7	2.8	3.2
TOTAL	**$4,676**	**$4,744**	**$3,754**	**$4,825**	**$4,610**	**$4,732**	**$4,183**	**$3,878**			**4.5%**	**4.7%**
ANNUAL CHANGE[n]	**–1.4%**	**–1.7%**		**4.7%**	**–2.6%**	**9.6%**	**7.9%**	**7.6%**				

a Fiscal year ends Sept. 30. **b** All figures exclude Conoco. Prior to 1991, figures include pharmaceutical research now part of DuPont Merck Pharmaceutical Co. **c** Spin off from Eastman Kodak on Jan. 1, 1994. **d** Figures for 1993 and 1994 based on company data and C&EN estimates. **e** Data refer to combined chemicals and to insurance and lubricant additives operations that are to be divided into separate companies. Prior to 1989, data include Tredagar Industries, which was spun off in July 1989. **f** Fiscal year ends June 30. **g** Fiscal year ends Nov. 30. **h** Prior to 1990, fiscal year ended June 30. **i** Data for 1993 and 1994 exclude Agrigenetics division, which formed the basis of a joint venture with Mycogen in December 1992. **j** Figures for 1993 and 1994 are estimates. Data from 1987 through 1992 stated to exclude Fisher Controls, which was sold in October 1992. **k** Fiscal year ends Oct. 31. **l** All figures restated by company to conform to industrial gases industry definition of R&D. Spun off from Union Carbide on June 30, 1992. **m** Figure for 1994 does not include R&D spending in organosilicons business sold in 1993. All figures reflect spin-off of Praxair on June 30, 1992. **n** For those companies reporting. **na** = not available.

up, it takes time to restart the R&D engine, he says. "So it's like a Slinky toy—you pull on the front end and the back end doesn't move for a while."

Industrial Research Institute's Annual R&D Trends Forecast, released in November, predicts a similarly pessimistic scenario for 1994, seeing the year as a continuation of the recession for industrial R&D in the U.S. Among a subgroup of 45 companies in chemicals and plastics, the Washington, D.C.-based IRI found that R&D budgets are expected to rise only 0.42% in 1994. And, as a percent of sales, R&D spending will remain at its 1993 level of 3.4% in 1994, although a second IRI study reports this figure as about 5%.

In a survey of its member companies, the Chemical Manufacturers Association (CMA) found that companies are optimistic about the near future, despite lackluster performance in 1993. With modest sales growth of about 5% expected in 1994, CMA says R&D spending is expected to rise only about 4% over 1993 to about $15 billion. Based on 91 companies reporting, 60% expect to increase spending, 28% expect to keep spending flat, and 12% anticipate declines. The discrepancies among C&EN's, Battelle's, and CMA's figures may be due not only to different survey sizes, but also to the fact that CMA's predictions were made in November 1993, before many companies had finalized their 1994 spending plans.

Of the 24 companies surveyed by C&EN, 10 projected increases in R&D spending in 1994 above the 2% inflation rate supplied by the National Science Foundation (NSF). Many of the companies predicting spending cuts in 1994—inluding Union Carbide and big spenders such as Dow Chemical and Monsanto—also cut spending in 1993. Decreases are planned by five companies, with the rest predicting spending to remain flat in terms of real dollars.

Included in C&EN's survey group are FMC and PPG Industries, whose businesses are somewhat more diversified than others in the chemicals area. Without these two companies, spending for the remaining 22 companies fell 2% in 1993 and is expected to fall another 2% in 1994. First Mississippi, from a very small base level, and FMC plan double-digit increases for 1994, whereas most others are keeping increases between 4 and 6%. Union Carbide's nearly 8% decrease, the largest reported decline, is due primarily to the sale of its organosilicons business in 1993.

Increases in pharmaceutical R&D spending slip to single digits

R&D spending by pharmaceutical companies seems to have entered a new era in 1993 and 1994—one of only single-digit increases. In surveying major pharmaceutical companies, C&EN found that 1993 R&D spending at six companies rose only 7% from 1992. The relatively small increase, half that of previous years, suggests that health care reform, as well as economic and pricing pressures, are affecting the industry.

C&EN's smaller sampling of companies compares well with the results of a larger survey recently reported by the Pharmaceutical Manufacturers Association (PMA) (C&EN, Jan. 17, page 7). PMA members encompass more than 100 research-based companies, including 40 biotechnology companies, which account for 90% of pharmaceutical sales within the U.S. PMA's research-based member companies reported an increase of about 10% in R&D spending in 1993. This increase, says PMA, is significantly less than the average annual increase of more than 16% from 1980 through 1992. Total R&D investments by the PMA-surveyed companies reached $12.6 billion in 1993.

For 1994, the drug industry R&D spending picture does not look much brighter. Pharmaceutical companies contacted by C&EN were extremely reticent about predicting their R&D spending levels for 1994. However, PMA found that 1994 R&D spending is anticipated to rise 9.5%, to $13.8 billion. According to PMA, this increase is the first single-digit increase since 1977.

However, contrary to holding down their increases in total dollars invested, companies will spend a higher percentage of their sales on R&D. In 1994, PMA says that companies intend to invest 18.8% of sales in R&D as compared with 18.3% in 1993. In a November 1993 survey of its member companies, PMA found that R&D spending has grown "substantially faster than sales for more than two decades"—R&D spending grew at a compounded annual rate of 14% from 1970 to 1993, whereas sales grew at a rate of about 12%.

C&EN's survey of six companies found R&D spending as a percentage of estimated sales reached about 13% in 1993, up slightly from 1992. Without Warner-Lambert, which reinvests a much lower percentage than other companies, R&D spending as a percentage of sales would be about 14%. Similarly, from its survey of eight pharmaceutical companies, Industrial Research Institute, Washington, D.C., reports reinvestment at 12%. Other than differences in survey size, PMA's data may be skewed by the inclusion of its biotechnology company members, since even the more established companies of these are known to spend 50% or more of their sales on R&D.

	R&D spending				R&D as % of sales			
$ Millions	1993	1992	1991	1990	1993[a]	1992	1991	1990
Eli Lilly	$ 960	$ 925	$ 767	$ 703	15.3%	15.0%	13.5%	13.5%
Merck	1,200	1,112	988	854	12.2	11.5	11.5	11.1
Pfizer	920[b]	863	757	640	12.4	11.8	10.9	10.0
Schering Plough	580	522	426	380	14.1	12.9	11.8	11.4
Upjohn	633[b]	549	491	427	17.1	15.1	14.4	14.1
Warner-Lambert	465	474	423	379	8.2	8.5	8.4	8.1
TOTAL	**$4,758**	**$4,445**	**$3,852**	**$3,383**	**12.9%**	**12.2%**	**11.5%**	**11.2%**
CHANGE FROM PRIOR YEAR	**7%**	**15%**	**14%**	**15%**				

[a] Based on estimated sales for 1993. [b] Based on company data and C&EN estimates.

The most consistent result among different surveys is that chemical companies seem determined to keep constant their R&D spending as a percent of total company sales. C&EN's average of 4.5% over the past decade agrees with findings by CMA and IRI. But, to keep this ratio constant, a decrease in R&D spending means a concurrent decrease in sales. In 1993, estimated overall R&D spending as a percent of sales for the 24 companies reported here will be 4.5%, down from 4.7% in 1992. An 11-year low of 4.3% occurred in 1984.

R&D spending also is gaining as a larger share of future-oriented spending. Based on 14 companies that appear in both C&EN's R&D and capital spending surveys, R&D spending as a percentage of combined research and capital expenditures will reach 39% in 1994, up from 36% three years ago. [Air Products, Arco Chemical, DuPont, Eastman Chemical, First Mississippi, FMC, H. B. Fuller, Great Lakes Chemical, Imcera, and Loctite are excluded because they do not appear in the 1994 capital spending survey (C&EN, Dec. 20, 1993, page 11)]. However, the gain on a percentage basis belies an overall spending decrease and that most capital expenditures are going toward process improvements and expansions as a means to curb costs, rather than into new investment.

R&D employment is being hurt somewhat by changes in spending and company reorganizations. Large employers such as Dow Chemical, DuPont, and Monsanto to have been cutting back R&D staff. However, all three companies now expect the cutbacks to level off. But IRI found in its surveys that only 5% of companies expect to increase hiring of new graduates, while 40% expect to decrease hiring, a downward trend that has continued for the past six years. Overall, R&D professional staffing levels at 90% of the companies are to remain unchanged or to drop from 1993 levels, according to IRI.

Not only is the amount of money companies are investing changing, but also the way in which it is being spent. Duga sees six major trends affecting industrial R&D: a short-term leveling of real R&D expenditures; an increase in contracting to other domestic performers such as universities and independent labs; the offshore acquisition of technological assets that are cheaper or more closely aligned with local market needs; the expansion or development of ad hoc alliances with other companies and with research facilities; a greater interaction with the federal labs; and, within individual industries, a more aggressive search, often via databases and/or a corporate technology "gatekeeper," to identify and acquire both finished and in-process technological assets.

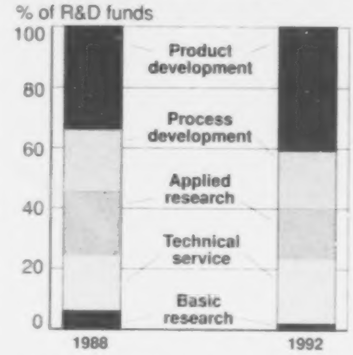
R&D management executives at Monsanto, Dow Chemical, and DuPont confirm that many of these trends are happening. They also describe an increased interest in collaborative, precompetitive research programs with other companies. Such alliances can serve as a means to expand companies' technology bases more economically. In the future, managers and analysts alike predict that companies will be coming together to work in "noncompetitive" areas, such as the environment, to develop technologies that benefit an entire industry.

Many industries—the chemical and petroleum industries are good examples—are cutting back on a lot of the basic research performed in-house, says Duga. "The research structure of major industries has changed in the sense that research is much more driven by operating unit needs as opposed to corporate-driven research that is much longer term [in outlook]." However, Duga believes this cutback on in-house expenditures, particularly in basic research, may be offset by a greater degree of research being performed on a contract basis. Others, such as IRI, expect significant decreases in grants for university research.

The idea that research is being driven more by company business unit needs is not a new one. Chemical company R&D managers tell C&EN that their companies have been exploring and strengthening the connections between business and R&D for some time. Selecting, aligning, or integrating technology with business planning and strategy has become an ideology of industrial R&D managers, in part helping them to justify the continued relevance.

Company managers also talk about being more selective in the use of resources and consolidating or leveraging certain research functions—analytical sciences, pilot-scale research, information sciences—to eliminate redundancies and make the R&D process more efficient and cost effective. There also is an increased emphasis on "shorter cycle times"; that is, bringing R&D results to the business units or marketplace more quickly. However, these changes do not mean that R&D serves only as a supporting function to business, but in many cases is expected to expand business areas through new product and process innovations.

Product development is growing share of R&D



Source: *Research • Technology Management*, **37**, 22 (1994)

For example, Dow has been reducing R&D or technical support for some of its mature businesses while giving more emphasis to breakthrough technologies that significantly enhance existing businesses or create new businesses. The company also has made some organizational changes to more directly align R&D with its businesses, explains Fred P. Corson, Dow's vice president for R&D. The company now has global R&D vice presidents for each of its major business groups. These individuals report both to Corson for the R&D function and to the business group vice president.

Three components of Dow's R&D—central research, health and environmental sciences research, and core technical capabilities that support the entire company such as analytical science, materials science, and engineering science—still are organized and funded on a corporate basis. Dow also has a global ventures business unit, formed about a year ago, that works with R&D and the business groups to find or create new business opportunities through technology innovation, acquisition, development, and commercialization.

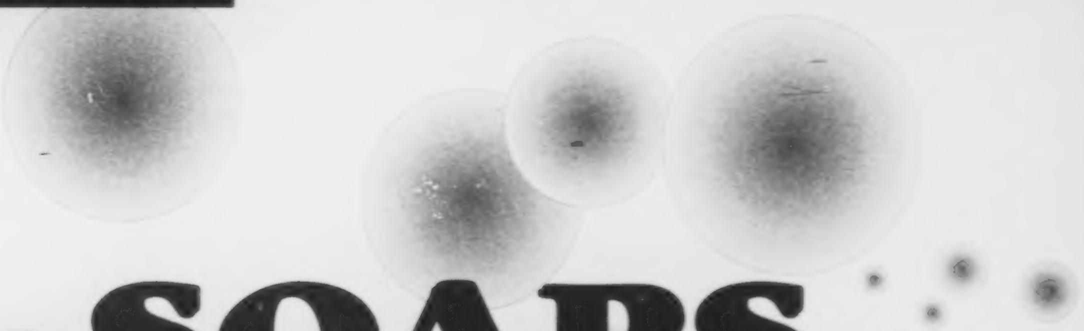
Companies still are retaining research with a long-term focus, but may now also tie this to business interests. Monsanto's biotechnology R&D effort, once a major, free-standing part of corporate R&D, has been transferred to the company's pharmaceutical and agricultural units, explains Philip Needleman, senior vice president and chief scientist at Monsanto. About half the number of scientists remain in corporate R&D, and are those who focus primarily on synthetic chemistry of broad interest to the entire company.

The effect has been to make a large portion of Monsanto's corporate R&D budget—more than $60 million—"disappear" into other areas by specifically aligning the research with operating businesses. Needleman says the support and nature of the company's biotechnology research hasn't changed at all, but that the move makes sense because products are now coming to fruition.

The trend of aligning research and business has become so prevalent that IRI, with the help of the Center for Innovation Management Studies at Lehigh University in Bethlehem, Pa., conducted its first survey to assess R&D spending and performance on the level of individual company business segments and corporate labs. Based on data for 1992, the survey looked to gain quantitative figures on the sources and allocation of R&D funds as well as on the outcome or return a company gets from R&D.

Contrary to "common wisdom," IRI found that just because an R&D organization depends upon the business units for funding doesn't mean that it will receive less support than if it received corporate funding. In the chemicals area, about 23% of R&D funding comes from corporate sources and the rest from business units. In terms of allocating funds, the chemical industry comes very close to averages: less than 5% goes to basic research, nearly 20% goes to applied research, about 20% goes to technical service, and the rest goes to product and process development.

Based on data going back to 1988, the study also found that a predicted shift in funding from exploratory research to product and process development has occurred. What was most difficult to measure, concludes IRI, is outcome or return from R&D. The survey identified "measuring and improving R&D productivity/effectiveness" as the largest problem research directors face. At the same time, this information is becoming increasingly desirable, even crucial, to have as firms report an increased scrutiny by top management who are looking to understand the impact of technology on business and the return from R&D expenditures. ☐



SOAPS & DETERGENTS

Industry relies increasingly on suppliers to keep up with fast-paced reformulations

Susan J. Ainsworth,
C&EN Houston

Judging from the meager rate at which it has been growing, the huge U.S. soap and detergent business appears to be mature. In 1993, for instance, industry shipments of soap and detergent products rose only 2% from the previous year to $14.9 billion, according to the Department of Commerce's U.S. Industrial Outlook report on cleaning preparations and cosmetics released this month. And in constant dollars, industry shipments are forecast to increase only 2% in 1994 and only slightly more than 2% annually for the next five years, the Commerce report adds.

However, this big, sluggish industry is far from stagnant. Motivated by concerns about the environment and getting more for its dollar in the midst of recessionary pressures, the public continues to put pressure on the soap and detergent market to keep evolving. Because household laundry products make up the largest segment of the detergent chemicals market, the consumer's vote—cast in terms of spending dollars—counts.

Consumers are still pushing hard for minimal packaging for their cleaning products. They want assurance that the products they buy contain "natural" ingredients that will not be harmful or irritating during use. The public demands that the cradle-to-grave life cycle of the products be environmentally sound as well. At the same time, consumers have come to expect more value, which they define as better product benefits at little or no extra cost. They want products that combine more than one cleaning function in a single product.

As a result, soap and detergent manufacturers have had to rethink their products from the inside out. The past several years have probably represented the "most dynamic period of change that the American detergent market has seen since the introduction of synthetic detergents in 1947," observes J. Keith Grime, associate director for product development at Procter & Gamble, Cincinnati. For example, just since 1990, the industry has witnessed the virtual conversion of the North American laundry detergent market to compact powders and, in 1993, the emergence of new liquid concentrate products—both of which require less product and packaging per wash load when compared with traditional detergent products.

"All of us who have been involved have had a fascinating and exciting ride on the R&D roller coaster as we provided technology that fueled the rapid-paced and highly competitive marketplace developments," Grime adds. "There has never been a dull moment."

The reformulation trend is creating many challenges for companies that produce and supply soap and detergent ingredients such as surfactants, builders, bleaching agents, and enzymes. Suppliers continue to have to "focus on the global market needs of the detergent industry and to serve those needs with technological development, technical support, and low-cost supply of ingredients," says Lewis G. Furman, marketing director for FMC's phosphorus chemicals division, Philadelphia.

Adds Lois Marquardt, business manager for sodium silicates at Occidental Chemical, Dallas, "Our business is oriented to respond to the changing requirements of the soap and detergent industry and we are continually making special grades to meet those needs."

Suppliers are increasingly being asked by their soap and detergent customers to partner with them to help develop crucial reformulation technology. They realize that "there's a much better chance for success at developing a new ingredient when they focus their efforts, picking one or two suppliers and really working with them rather than asking 10 suppliers to make bids," says David LeBlanc, surfactants business director for Hoechst Celanese, Charlotte, N.C.

"Our customers have to pick suppliers who have the capability to manipulate processes and molecules to give them the properties they need," says William Huisking, vice president of the performance chemicals division of Lonza, Fair Lawn, N.J., a company that plows in excess of 15% of its sales back into R&D for what it deems its "strategic products."

"Partnering—getting together to talk about our customers' formulation needs—only makes sense, because we are the experts on zeolites and silicates and they are the experts on laundry detergents," says Thomas H. Gudowicz, business manager for zeolites at PQ Corp., Valley Forge, Pa. "Our customers are really opening up and realizing that they have to use suppliers as an extension of their R&D, manufacturing, and logistics systems."

Soap and detergent producers use partnering relationships to help them keep up with the many demands of a complex marketplace. Simply giving presentations or providing technical literature to customers on suppliers' products isn't good enough anymore, notes Jeannene Ackerman, vice president for laundry products at Witco, New York City. In addition to wanting more hands-on technical help, "customers are also asking suppliers to determine whether patents may be an impediment to a specific formulation, or if a premanufacturing notice is required before a new ingredient can be produced," says Lawrence Moss, Witco's vice-president for personal care, household, industrial, and institutional surfactants.

"Soap and detergent customer demands and needs have focused more on quality in the past few years," adds Marquardt. "[Manufacturers] are establishing and implementing programs to evaluate production processes and procedures and to measure raw material quality consistency. The goal is to systematically select suppliers on a quality basis. All of our plants have a working in-house statistical process control/statistical quality control program that enables us to respond to customer demands. We have the capability to provide customers with specific data that measure all phases of our process and finished product."

Partnering also takes some of the cost burden off of soap and detergent manufacturers, allowing them to spread some of the cost to suppliers. "Customers don't have unlimited resources. They have to optimize what they have and one way to do that is to rely more upon suppliers," says Lonza's Huisking.

This reliance is increasingly important to soap and detergent manufacturers as they find it tougher to pass on development costs in the prices of their consumer products. Although newer detergent products offer consumers additional benefits (such as being more environmentally benign), they don't necessarily allow manufacturers to sell those benefits at a premium over the products they replace.

Profiting on new products is especially tough as the lingering recession continues to send consumers gravitating toward "value" brands rather than premium labels. To compete with such brands and with products sold at discount stores, which have the buying leverage to discount even premium products, soap and detergent manufacturers have had to slash prices on name brand products sold in all outlets.

"Manufacturers' claims that they have had to reduce prices for finished detergent products are true," says John Parker, business manager for persalts

Solvay Interox photo

PQ Corp. photo

Suppliers' technicians analyze detergent ingredients, checking thermal stability of persalt (above) and viewing zeolite crystals with a scanning electron microscope.

The anatomy of a laundry detergent

All laundry detergents perform the same basic functions, but there's broad diversity among detergent formulas. Although they may contain the same basic components such as surfactants or builders, for example, each formulation may vary in the type and amount of those components.

Surfactants

The surfactant or surface-active agent improves the wetting ability of water; loosens and removes soil with the aid of wash action; and emulsifies, solubilizes, or suspends soils in the wash solution.

Surfactants are organic compounds consisting of two parts: a water-attracting (hydrophilic) portion and a water-resistant (hydrophobic) portion. The hydrophobic ends attach themselves to the soil particles or to the fabrics being washed while the hydrophilic ends are attracted to the water. The surfactant molecules surround the soil particles, break them up, force them away from the surface of the fabric, then suspend the soil particles in the wash water.

Detergents may contain more than one kind of surfactant. These surfactants differ in their ability to remove certain types of soil, in their effectiveness on different fabrics, and in their response to water hardness. Surfactants are classified by their ionic (electrical charge) properties in the water. Anionic, nonionic, and cationic are the major surfactant types used in laundry products.

Builders

The builder in a detergent formulation enhances or "builds" the cleaning efficiency of the surfactant by inactivating water hardness minerals. Builders soften water by sequestration, precipitation, or ion exchange. Most builders provide a desirable level of alkalinity, which aids in cleaning, and disperse and suspend soils to prevent their redeposition.

Antiredeposition agents

Antiredeposition agents may be made from complex cellulosic materials such as carboxymethyl cellulose or synthetic materials such as polyethylene glycol and polyacrylates. They aid in preventing loosened soil from redepositing onto cleaned fabrics.

Corrosion inhibitors

Corrosion inhibitors, usually sodium silicate, help protect washer parts from corrosion.

Fluorescent whitening agents

Fluorescent whitening agents or brighteners are complex organic molecules that adhere to fabrics as though they were dyes. Ultraviolet energy is absorbed, converted, and emitted as visible blue light to enhance fabric appearance and maintain whiteness or brightness.

at Solvay Interox, Houston. For example, "The cost per wash for liquid detergents, which up to 18 months ago used to carry a significant premium, is now much more in line with the cost of using powdered detergents."

"Of course," says Hoechst Celanese's LeBlanc, "that price pressure comes back to the companies selling raw materials." Parker adds, "Lower costs in the stores mean the manufacturers must continue to seek economies wherever they can find them" and that affects Solvay Interox's business. He adds, "The focus on supplier value continues to increase; the need for close customer contact is more vital today than ever before."

Indeed, suppliers are pinched by the additional price pressure, cost, and time required to meet their customers' growing partnering demands, but the investment eventually pays off, says Michelle Borland, market manager for detergent raw materials at Texaco Chemical, Houston. Although Texaco Chemical has had to devote more of its R&D resources to joint projects with its soap and detergent customers, "It's an additional way to start us working as a team with them and that's a good way to build a strong relationship."

For one thing, Borland continues, partnering has "allowed us to get in on the ground floor with customers on projects." PQ's Gudowicz agrees, adding, "We seem to be getting an earlier look at what products customers want to formulate in the future. We know the specific property that they are looking for and so we have a chance to formulate new products in concert with them."

Having the inside track on what soap and detergent producers are looking for is increasingly important. As they try to position any new product developments in soap and detergent formulations, suppliers have also been fighting to keep their established ingredients on the winning side of the reformulation war. Unavoidably, some products have been and will continue to be crippled by reformulation trends that have led the industry toward replacement products.

Although total demand for detergent chemicals is slated to increase less than 3% per year through 1996, prospects for certain ingredients that are compatible with reformulation trends are much better, according to a detergent chemicals study done last year by Cleveland-based consulting firm Freedonia Group. For example, the best growth opportunities among detergent chemicals will center on nonphosphate builders such as zeolites and high-priced, smaller volume chemicals such as enzymes, says Freedonia industry analyst Luci Young.

Likewise, Young notes that industry trends toward the development of multifunctional products and liquid detergent formulations will favor chemicals that are compatible with a wide range of other chemicals. "As the popularity of multifunctional detergents continues, both enzymes and bleaches will experience above-average growth," she says.

Concentrated detergents

Certainly no recent reformulation trend has shaken up the soap and detergent chemicals market like the massive move to concentrated laundry detergents.

Indeed, growth in the new concentrated liquid and powder formulations will boost future growth of surfactants, which are needed in greater concentrations in these products. Partly because of the proliferation of concentrated products, in 1993, industry shipments for surfactants used in soaps and detergents increased more than 3% to \$3.5 billion, or 2% in constant dollars, according to the Commerce report. Exports increased more than 3% to \$567 million, while imports increased to \$210 million, producing a positive trade balance of \$357 million, the Commerce report adds. In 1994,

Processing aids

Processing aids cover a considerable list of ingredients including sodium sulfate, water, and solvents such as alcohol or xylene sulfonate. They provide the product with the required physical properties for its intended use. Sodium sulfate, for example, helps provide crisp, free-flowing granules. Alcohols are often used in liquid products where they serve as solvents for the detergent ingredients, adjust the viscosity, and prevent product separation. Because the water content of liquids is fairly high, alcohols also protect the product under extremely cold storage conditions by lowering the freezing point.

Colorants

Colorants are added to lend individuality to the product or to dramatize a special additive that contributes to product performance. Additionally, blue colorants may provide a bluing effect that imparts a desirable blue-white color to white fabrics.

Fragrances

Fragrances have three functions, regardless of the specific scent used. They cover the undesirable odors of the detergent itself and of the soils in the washing solution. Plus, they impart a pleasant scent to fabrics, thus reinforcing the cleaning performance. Additionally, a fragrance contributes to the character of the product. Some detergents are offered in unscented versions, appealing to consumers who prefer little or no scent on laundry. They may also appeal to people whose skin is sensitive to fragrance ingredients.

Opacifiers

Opacifiers are used in some liquid products to provide a rich, creamy, opaque appearance.

Oxygen bleach

Oxygen bleach provides the detergent with an all-fabric bleaching action for stain and soil removal.

Enzymes

Enzymes aid in breaking down complex soils, especially proteins such as grass and blood, so that they can be more easily removed by other detergent ingredients.

Suds control agents

Suds supressors inhibit sudsing or control it at a low level. Special long-chain soaps are one class of compound used to control sudsing in granular and liquid laundry detergents.

Fabric softening agents

Fabric softeners impart softness and control static electricity in fabrics. Cationic surfactants such as quaternary ammonium compounds are commonly used.

Source: Soap & Detergent Association

the value of industry shipments will increase 2% in real terms.

The Freedonia report on detergent chemicals has basically the same forecast. Demand for surfactants used in household and industrial and institutional detergents will increase 2.1% per year through 1996, the consulting firm predicts.

One company that will be well positioned to take advantage of growth across the board in surfactants is Huntsman Corp., which is now expected to be formed no earlier than the end of next month through the completion of Huntsman Financial Corp.'s purchase of Texaco Chemical. The company's purchase of Monsanto's linear alkylbenzene (LAB) business last month, "makes the new Huntsman Corp. a much stronger player in the detergent business, because now not only will we be a full-range nonionics supplier, we will have anionics as well," says Borland. "With two key pieces of most detergent formulations, we will have a broader product line to offer our customers. These acquisitions show a very strong commitment to the detergent business."

Nonionic surfactants

Among all surfactants, nonionics will provide the greatest opportunities because of their ease of incorporation into liquids, better resistance to hard water ions, and advantages over anionics in cleaning synthetics, as well as moderate cost, says Freedonia's Young.

Among nonionics, the current market forecast is that demand for ethoxylated products will grow in most traditional applications, says LeBlanc. "In addition, we expect growth in the market owing to manufacturers' substituting ethoxylates for existing surfactants where ethoxylates offer superior properties." Growth rates for linear alcohol ethoxylates could go as high as 5 to 7% per year, "if some of rumored substitutions do occur," says LeBlanc.

However, one factor that limits the wholesale substitution of nonionics for other surfactants is limited production capacity, says LeBlanc. With this in mind, last month Hoechst Celanese began construction of a new ethoxylates unit at its Clear Lake, Tex., plant. When the plant starts up in fourth-quarter 1994, the facility will have capacity to produce 150 million lb per year of alcohol ethoxylates and other ethoxylated products. "This new facility will allow us to supply existing customer demands and will give us flexibility for expansions and new products," adds LeBlanc.

Nonionics have also benefitted from the reformulation trend toward concentrated detergents. Now that most of the major producers of detergents have completed the switch over to concentrates, industry demand for synthetic-based linear alcohol ethoxylates, which go into their premium brand concentrates, has been stable this year, says Borland.

However, growth for nonyl phenol ethoxylates, which go into less expensive, private label detergents has been strong. That's because these private label manufacturers are still in the midst of formulating and launching their own copycat concentrated formulations, and sales of these less expensive brands are booming as consumers try to save money in these leaner times.

As the economy improves, Borland does not expect sales of private label brands and nonyl phenol ethoxylates to wane. "Private label formulations have become much more sophisticated and their manufacturers are able to react in the marketplace a lot faster than they used to. So it's not likely that consumers are going to run out and buy brand products again as soon as they get a little more disposable income."

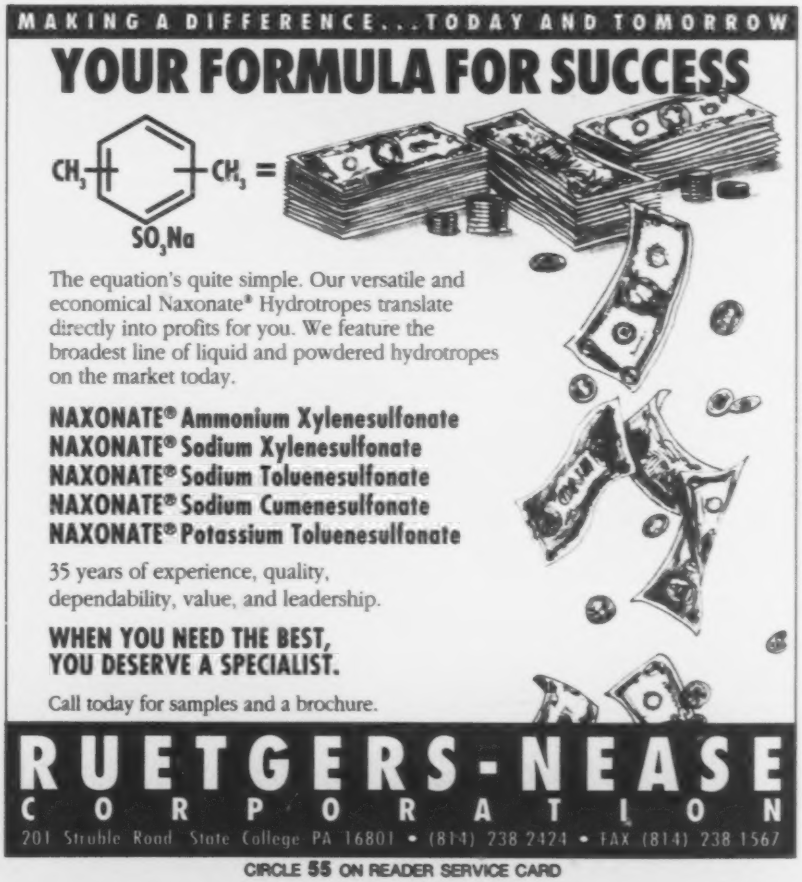
Partly reflecting its faith in the future of the detergent ethoxylates market, last month Texaco Chemical brought on stream a 25 million-lb-per-year ethoxylates expansion at its Port Neches, Tex., facility. Also at Port Neches, this coming July, Texaco Chemical will start up a propylene oxide plant, which would make the company "the only ethoxylates producer that will be basic in both ethylene oxide and propylene oxide," says Borland.

This statement is made assuming that Huntsman exercises its two-year option to buy a 50 or 100% interest in that plant. To capitalize on this new captive raw material source, the company is launching a new line of ethylene oxide-propylene oxide products for the automatic dishwashing market.

Surfactant producers that make products from petrochemical sources continue to face growing competition from producers of fatty alcohol-based surfactants made from renewable raw materials such as palm and coconut oils and animal fats, which consumers view as more environmentally friendly. "With the green movement, the trend is toward [use of] raw materials for surfactants based on natural products," says Erik Rietkerk, head of worldwide sales and marketing for Singapore-based Salim Oleochemicals.

But the balance between natural- and synthetic-based surfactants is "absolutely not being decided totally by consumer demand," says Borland. Soap and detergent manufacturers want the flexibility to use oleochemical- (natural-based) or petrochemical-based raw materials so that they can purchase the type that is more economical at a given time. Texaco and Vista Chemical are two companies that produce an ethoxylate that so closely resembles the natural counterpart that they can be interchanged easily in a production process.

Vista Chemical agrees that, for the most part, customers want to maintain flexibility by being able to purchase both petrochemical- and oleochemical-based surfactants, says Tom O'Brien, manager of surfactant sales at Vista Chemical, Houston. "There will always be some small segment of the market that demands natural, but for the most part, [formulators] are now using good science in choosing their surfactant raw materials."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Natural fatty alcohol prices have been higher than those for their petrochemical-based counterparts over the past few years. Most notably, coconut oil prices jumped from 20 cents per lb to 30 cents per lb between early November and mid-December. So synthetic versions look a little more attractive now, even though producers of some petrochemical-based products raised their prices during the course of 1993.

"There will always be short-term disparities in pricing between oleochemical alcohol, petrochemical alcohol, ethoxylates, and LAB because there are a lot of factors that set pricing," says O'Brien. "But over the long term, these products will have price parity if they want to remain as workhorse surfactants."

Rietkerk agrees. "I think natural-based alcohols will have to move toward the pricing level of synthetics in order to be competitive, especially in North America." He also agrees with Borland, who predicts, "Over time, as more natural alcohol capacity comes on, you will see price parity between the two products."

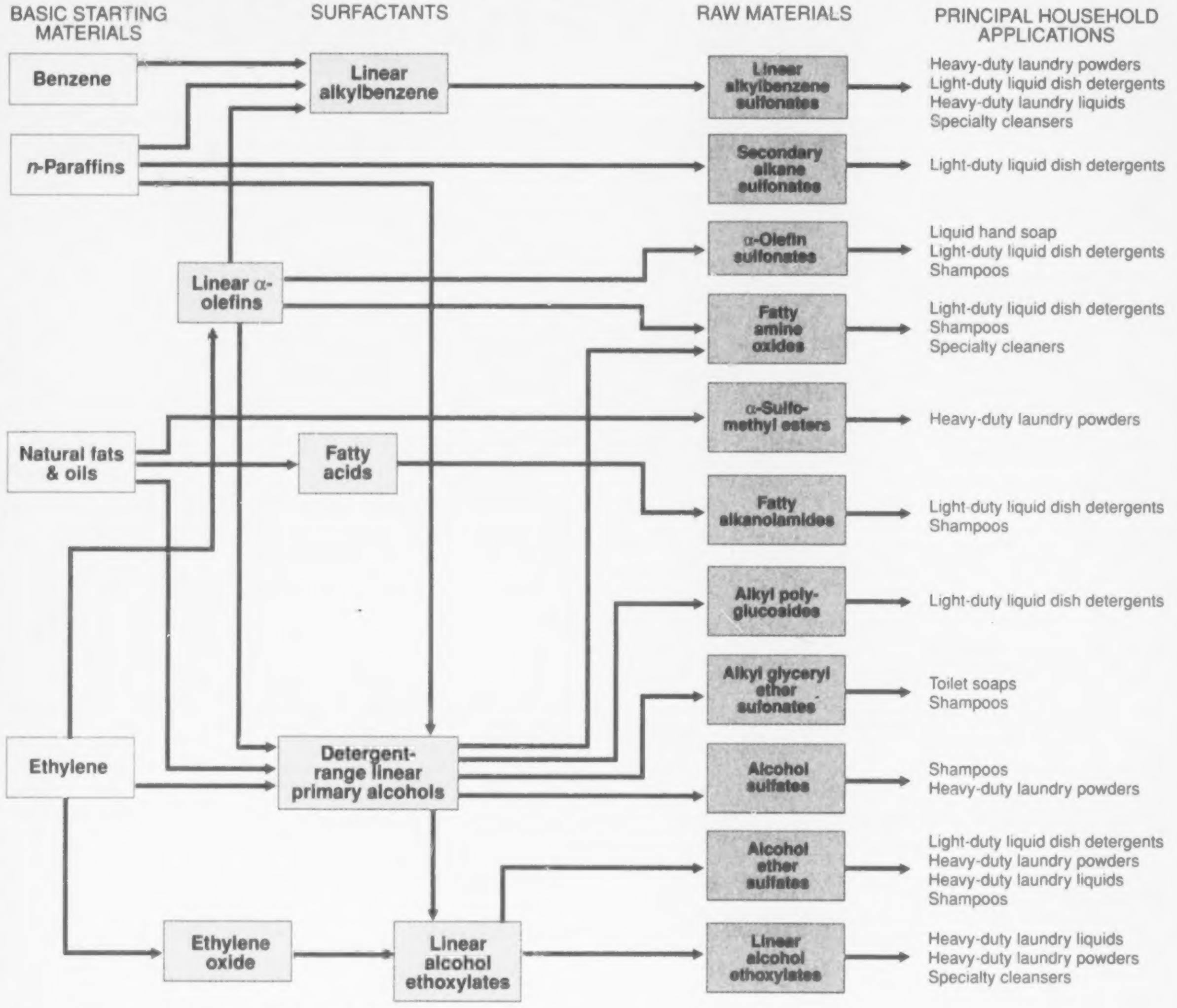
Alcohol capacity boost

Although capacity growth in petrochemical-based surfactant raw materials has been limited mostly to minor expansion projects, producers of oleochemicals have been investing in significant capacity additions, Rietkerk points out. Indeed, the industry is producing more oleochemical-based alcohols. In 1993, C_{12} oleochemical alcohols made up roughly 50% of worldwide fatty alcohol capacity, which totaled 1.82 million metric tons, according to Joel Houston at Mamaroneck, N.Y.-based consulting firm Colin A. Houston & Associates. That's up from 1991, when oleochemical-based alcohol represented only 42% of total world fatty alcohol capacity, which then totaled 1.57 million metric tons.

By early March, Salim Oleochemicals will bring on stream a $230 million oleochemical plant on the Indonesian island of Batam with a capacity of 60,000 metric tons of fatty alcohol per year. The expansion will boost the company's fatty alcohol production to about 100,000 metric tons per year, making it the world's third largest producer of fatty alcohol behind Germany's Henkel and Procter & Gamble, according to Salim.

Salim already operates an oleochemical plant at Belawan, near Medan on the island of Sumatra. The group also

Surfactants for household detergents—petrochemical raw materials and uses


BASIC STARTING MATERIALS
SURFACTANTS
RAW MATERIALS
PRINCIPAL HOUSEHOLD APPLICATIONS
Benzene
n-Paraffins
Linear α-olefins
Natural fats & oils
Ethylene
Linear alkylbenzene
Fatty acids
Detergent-range linear primary alcohols
Ethylene oxide
Linear alcohol ethoxylates
Linear alkylbenzene sulfonates
Secondary alkane sulfonates
α-Olefin sulfonates
Fatty amine oxides
α-Sulfomethyl esters
Fatty alkanolamides
Alkyl polyglucosides
Alkyl glyceryl ether sulfonates
Alcohol sulfates
Alcohol ether sulfates
Linear alcohol ethoxylates
Heavy-duty laundry powders
Light-duty liquid dish detergents
Heavy-duty laundry liquids
Specialty cleansers
Light-duty liquid dish detergents
Liquid hand soap
Light-duty liquid dish detergents
Shampoos
Light-duty liquid dish detergents
Shampoos
Specialty cleaners
Heavy-duty laundry powders
Light-duty liquid dish detergents
Shampoos
Light-duty liquid dish detergents
Toilet soaps
Shampoos
Shampoos
Heavy-duty laundry powders
Light-duty liquid dish detergents
Heavy-duty laundry powders
Heavy-duty laundry liquids
Shampoos
Heavy-duty laundry liquids
Heavy-duty laundry powders
Specialty cleansers

Source: SRI International, Chemical Economics Handbook

has a pre-World War II 15,000-metric-ton-per-year fatty alcohol plant in East Germany, which it will tear down and replace with a new plant that will produce between 30,000 and 60,000 metric tons of fatty alcohols by 1997 or 1998.

As chemical producers and soap and detergent manufacturers such as Procter & Gamble add oleochemical-based fatty alcohol capacity, it encourages the industry to reformulate toward these products, cutting into the market for anionic surfactants such as linear alkylbenzene sulfonate (LAS). But even so, reformulation away from LAS hasn't happened to the degree forecast one and two years ago, says O'Brien.

As is the case in the detergent alcohols market, pricing of LAS relative to other surfactants plays a big part in determining its contribution to today's detergent formulations. "Today, LAS pricing is very competitive with its alcohol-based surfactant counterparts," says O'Brien. Reflecting its confidence in LAS, Vista Chemical announced earlier this month that it will invest $100 million in a project that will reduce operating costs at its Baltimore detergent alkylate facility (C&EN, Jan. 17, page 8).

The LAS market has rebounded from negative laboratory tests showing that it, like other sulfonates, did not biodegrade as readily as many other surfactants. Larry Britton, senior research group leader at Vista Chemical, a producer of LAS, questions the ability of laboratory testing methods by themselves to accurately predict the fate of a given chemical in a given environmental setting.

"The anaerobic test methods that regulatory guidelines routinely call for fail to take into account conditions present in nature that allow for biodegradation despite lack of oxygen," comments Britton. Anaerobic biodegradability tests are used to predict whether chemical compounds are likely to remain intact and build up over time in environments that lack oxygen—such as swamps, water-saturated soils, peat bogs, or sediments from lake or river bottoms—potentially reaching levels harmful to organisms in these ecosys-

CIRCLE 11 ON READER SERVICE CARD →

tems. "It is possible that certain substances known to require molecular oxygen to biodegrade will show no degradation in anaerobic digestors and laboratory tests, yet will biodegrade in natural environments that are typically labeled as anaerobic," Britton adds.

Using LAS (which requires oxygen to degrade) as a test substance, and monitoring carbon dioxide production in river sediment designed to be anaerobic, Britton and his colleagues were able to confirm biodegradation of LAS in the sediment. Laboratory tests, he says, fail to account for oxygen flux that occurs in natural anaerobic environments, which are seldom completely free of oxygen.

Despite these findings, competitors are busy developing products that can stand in for LAS while boasting a more positive biodegradability profile. "We are really trying to capitalize on [the trend toward more biodegradable surfactants] by doing more testing to demonstrate the biodegradability of our existing products," says Lonza's Huisking. "In what is probably the primary focus of our research and development effort right now, we are trying to build molecules that are more biodegradable for certain applications."

Indeed, a number of newer surfactants are taking some market share from LAS in selected market segments in some world regions, according to a report on LAS issued in early 1993 by SRI International. These include *n*-paraffin sulfonates, α-sulfomethyl esters of detergent alcohols, and alkyl polyglycosides. "These surfactants are often promoted as having faster biodegradability or, in the case of the methyl esters and alkyl polyglycosides, for being based on natural raw materials," the SRI report adds.

To capitalize on this trend, just over a year ago Henkel Corp.'s Ambler, Pa.-based CD Division launched its family of Glucopon surfactants that are composed of alkyl polyglycosides. These compounds are made from natural raw materials—glucose derived from corn and fatty alcohols made from coconut and palm kernel oils. Then earlier this month, Henkel expanded that line with the introduction of several types of Glucopon surfactant concentrates, which are composites of Henkel's Glucopon surfactants and conventional surfactants. The concentrates can be used in the household and

Continued on page 44

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Continued from page 41

industrial and institutional markets in liquid dish and liquid hand soaps, concentrated laundry liquids, and for cleaning hard surfaces.

"Our Glucopon surfactant concentrates respond to the needs of the marketplace," says Anthony J. DeRosa, vice president of Henkel's detergent and personal care divisions. "Right now, consumers want more value for their money, along with mildness, without sacrificing cleaning performance, and they favor products made from natural raw materials. Manufacturers are committed to meeting consumer requirements, and they are under price competition and must reduce total costs."

The products also deliver the "unusual combination of detergency and mildness. They also exhibit good foaming, ease of dilution, and they do not gel," DeRosa says. The concentrates are highly active, with active ingredients making up as much as 50% of the formulation. DeRosa adds that the concentrates offer good total value, and manufacturers can obtain superior performance at lower surfactant levels than are typical with conventional surfactants.

Builder systems

Indeed, detergent formulations continue to evolve not just through changes in the surfactants mix, but also through changes in the choice of builders. Demand for builders in all detergent and cleaning end uses is expected to increase nearly 3% per year until 1996, according to the Freedonia report. Nonphosphate builders such as zeolites (which are commonly used in powder detergents) and sodium citrates (used in the growing liquid laundry detergent segment) will achieve above-average growth, according to the report.

However, owing to environmental concerns, phosphate builders will face continuing declines. Phosphates are popular builders because of their effectiveness, reasonable cost, and safety for use with appliances, fabrics, and humans. They are nontoxic to aquatic life as well. The problem is that in combination with other nutrients such as carbon, nitrogen, and potassium, phosphates nourish algae and plant growth in lakes and streams. Lack of oxygen for fish is one of the consequences of this eutrophication of water.

For now, phosphate builders have not

Detergent chemicals use will continue to grow

Millions of lb	1991	1996	% annual growth (1991–96)
Builders	3.905	4.510	2.9%
Surfactants	1.615	1.790	2.1
Bleaches	45	65	7.6
Enzymes	12	20	10.8
Other	223	265	3.3
TOTAL	**5,800**	**6,650**	**2.8%**

Source: Freedonia Group

been regulated out of household dishwashing applications nor out of dishwashing and laundry products for the industrial and institutional market. The regulatory picture is a little bleaker for phosphate-based household laundry products. Because most states have banned phosphate use in laundry products, nearly all manufacturers have removed it from their formulations.

As discouraging as this decline in a major outlet for phosphates has been, FMC's Furman says, the company "continues to view its phosphorus operations as a core business." Total 1993 North American demand for sodium tripolyphosphate (STPP) in consumer cleaning compounds reached approximately 690 million lb, according to FMC. An additional 280 million lb is used in industrial applications, and about 80 million lb is exported. Projected total 1993 worldwide STPP production and consumption is about 2.5 million metric tons.

"To ensure that FMC continues as the low-cost producer of STPP and is globally competitive," says Furman, "the company is making changes in its phosphorus operations to reduce costs and maintain our cost advantage."

Although U.S. laundry detergent manufacturers have been forced to remove phosphates from their products, it has not been easy to find a replacement chemical that works as well. "The ideal builder system remains elusive, [because] science has not yet found the perfect balance between biodegradability, hydrolytic stability, sequestration capability, and cost," says Grime of Procter & Gamble.

Carbonate and silicate systems supported by polyacrylate dispersants now have a predominant role as builders in today's laundry detergent formulations. "Citrate has reappeared in some products to support building, dispersion, and solubility. However, its cost and limited sequestration ability have confined it to a supporting role" in the laundry detergent marketplace, Grime adds.

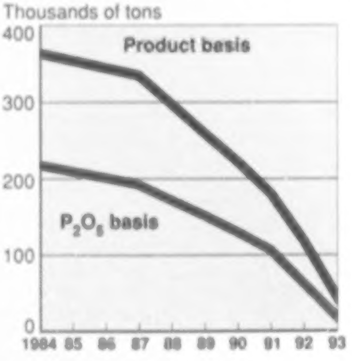
Zeolites dominate builders

More than any other builder, zeolites have emerged as the preferred phosphate substitute. Their ability to remove calcium ions from the wash water solution is well known. However, as detergent R&D organizations around the globe focus their formulation efforts on zeolites, they are taking advantage of zeolites' other beneficial functions, says PQ's Gudowicz. Zeolites are effective in removing manganese and iron ions that can stain fabrics. They are less effective in removing magnesium ions, but, when coupled with silicates, they present a very cost-effective package, he says.

In the recent move to higher density concentrated detergents, the ability of zeolites to adsorb liquid nonionic surfactants to keep the product lump-free and free-flowing plays an important role in the manufacturer's production and particle formation scheme. Another benefit is that the high adsorbtive surface area of zeolites can trap dispersed particles and keep them from redepositing on the fabric. Finally, zeolites are safe to both humans and the environment, Gudowicz adds.

Besides acting as a detergent builder, zeolites function as a particle formation process aid, which is important as detergent manufacturers move away from classical spray-drying to alternative forms of particle-making in an effort to produce denser powder concentrates. This secondary role of zeolites "will guarantee the use of these materials for years to come," says Grime.

Use of phosphates in home detergents is falling in U.S.



Source: SRI International, Chemical Economics Handbook

Anhydrous zeolite demand in the U.S. has grown from about 50,000 metric tons in 1985 to 300,000 metric tons in 1993, according to PQ. Gudowicz foresees modest growth that could boost consumption to 400,000 metric tons (450,000 metric tons on a hydrate basis) per year by the end of the decade.

Ethyl Corp., another producer of zeolites, says growth has leveled off to about 5 to 7% per year following the explosive growth of the past few years when legislation banning use of phosphates in laundry detergents sparked a massive reformulation effort by the major manufacturers. "There is still some switching over to zeolites by manufacturers of local brands in areas where phosphate use has not been banned," says John McChesney, a marketing communications manager at Ethyl in Baton Rouge, La.

Citing growth in this market, PQ has been rapidly expanding its zeolite capacity over the past couple of years. In 1993, it brought on capacity at new plants in Bangkok, Thailand, and Seoul, South Korea, making PQ "the largest zeolite producer in the world," says Gudowicz. Asia, he notes "is a real growth market for zeolite-built detergents."

Although zeolites are the preferred stand-in for phosphates in household laundry detergents, they cannot be used as a one-to-one replacement for phosphates. "You can't yank out phosphate from a detergent formula, throw in zeolite, and expect to be home free," says David T. Hermann, a marketing manager for PQ's industrial chemicals division. "This was the lesson the industry learned in the early 1980s." Since then, the industry has reformulated, using new surfactant systems and cobuilders (such as silicates and polymers) so that the final formulations now perform as well as the old phosphate formulations, he notes.

Another challenge zeolites present is that they are insoluble crystals. Therefore, they can only be included in liquid detergents if special attention is given to the prevention of particle settling through the structured liquid technology, which basically prevents phase separation, says Gudowicz. In the past, zeolites have been avoided in liquid systems, he says, and an alternative builder such as sodium citrate has been used or the formulation contained no builder at all. "However, we are now seeing zeolite-built liquid laundry detergents being marketed in the U.K., Italy, and Australia."

Sodium silicate plays an important role in the success of zeolite-based concentrated laundry powders. It acts as a binder (that aids in forming a dust-free granule), an anticorrosion agent, an alkali (to aid in soil removal), and a minor builder—mainly for magnesium sequestration. Today's premium formulations contain only 3 to 5% silicate to 35% zeolite. This is a sharp reduction from older high-phosphate formulations that contained more than 10% silicates. "While the change was good for the company's zeolite business," Hermann adds, "we lost half of our silicate market [share] overnight when the market went concentrated and [when it] pulled phosphate out."

Solvay Interox photo

Technician measures bulk density of persalt sample.

Dishwashing products

While demand for zeolites levels out in the laundry products segment, zeolite producers are watching for opportunities in the automatic dishwashing segment. Hermann says PQ is doing some research into automatic dishwashing products that are based on powdered silicates and zeolites. Although changes in nonphosphate legislation may be needed to stimulate widespread reformulation, the industry is watching with interest to see if the several minor nonphosphate automatic dishwashing products introduced in 1992 will be successful in the market.

Some manufacturers have developed improved formulation technology to produce phosphate-free automatic dishwashing products, but manufacturers in countries where phosphate is not a concern prefer phosphate-based detergents for their proven performance, says Peter P. Carfagno, detergent products technology manager for phosphates at FMC's Chemical R&D Center in Princeton. "When European nonphosphate products are tested in the U.S., we are told they do not satisfy the performance needs of most U.S. customers," he adds. This is due, among other things, to differences in U.S. machine design and use of water softeners in Europe, he explains.

In the U.S., too, compact, phosphate-built automatic dishwashing products have been gaining momentum in the marketplace. While only one such product was introduced in 1992, several appeared over the course of 1993, and more are expected to be launched this year, says Carfagno.

To capitalize on this trend, FMC has developed special grades of phosphates tailored to the needs of formulators of detergents for compact automatic dishwashers. For example, FMC is supplying specialized tripolyphosphate products that provide the appropriate solubility and dispersability required for automatic dishwashing formulations, says Carfagno. "As ultra automatic dishwashing products become more dense, producers find they must work on the solubility of their formulations. Not only must they look at the weight-volume efficiencies of the ingredients, but they must also focus on the formulation's dissolving characteristics. Formulations are developed and processes are designed to ensure good solubility within the low dose requirements of the compact format."

Phosphate-based dishwashing formulations are preferred not only in the household dishwashing market, but in the industrial and institutional segment as well. In fact, demand for phosphate-based industrial and institutional formulations is growing because of the trend toward collecting statistical information that helps match specialized product forms to specific cleaning needs, says Carfagno.

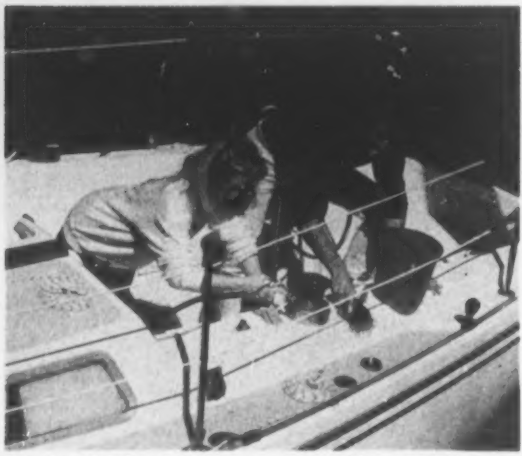
New data systems can monitor the dispensing of the detergent and tailor its dosage to the cleaning demands of the washing situation at hand, which may change by the time of the day and type of meal being served. Fine-tuning the product results in the more efficient use of chemicals for end users, he notes. Dispensable product forms such as blocks and slurries are integral to this type of cleaning, and phosphates are often key ingredients in producing these special dispensable detergent forms.

"Industrial and institutional products are formulated with phosphates because when the formulator and end user need assurance of good hygiene and that surfaces are sanitized, no one can challenge the job that phosphate does in removing soil and enhancing overall cleaning," says Carfagno. "Good cleaning is an essential first step needed to ensure good sanitizing. So, we see a good outlook for phosphate in both food plant and restaurant cleaning applications."

Detergents with bleach

To be sure, household consumers, like those in the industrial and institutional market, are concerned with getting good cleaning power from the products they buy. In the laundry segment, formulators have been working to develop products that clean clothes effectively even while the temperature of wash and rinse water used in energy-conscious U.S. households drops. One way to solve this dilemma has been to add nonchlorine bleach to detergent formulations.

It's not surprising, therefore, that detergent-with-bleach laundry products have led the multifunctional detergent trend. During 1993, almost all detergent makers, including private label formula-



Marine cleaning solutions contain sodium percarbonate.

tors, have developed a detergent-with-bleach concentrated product, observes Richard A. Merluzzi, FMC's business director of peroxygen specialty products.

These liquid and powder products have gone from holding 3.5% of the total household laundry market in 1986 to capture a 10.9% share in 1993, according to Procter & Gamble's Grime. In Canada, the penetration of detergent-with-bleach products stands at about 9%; in Latin America, these products have expanded quickly to capture roughly 10% of the market since their introduction there in 1992.

Perborates—solid carriers of active oxygen that form hydrogen peroxide in solution—are the predominant bleaching component in household detergents today. Among perborate forms, in the U.S. perborate tetrahydrate has been displaced by perborate monohydrate, which is more soluble under the relatively cool U.S. laundry wash water conditions.

In North America, perborate growth is expected to continue at over 5% per year as additional detergent brands are formulated with perborate bleach and as existing brands gain increased consumer acceptance, according to Richard Wardell, industry manager of the peroxygen chemicals division at Ridgefield Park, N.J.-based Degussa Corp. In early 1993, responding to growth in this market segment, Degussa brought on stream a new plant in Antwerp, Belgium, to produce sodium perborate monohydrate to serve worldwide demand.

Although growth in demand for perborate monohydrate has been strong, perborate pricing has been relatively weak, Wardell reports. The U.S. recession, which has moderated wash load volume growth to some extent, has had a depressing effect on overall detergent pricing. That, in turn, has exerted downward pressure on ingredient suppliers.

Another blow to the perborate market is possible competition for market share by percarbonates. "In the detergent-with-bleach product segment, we see potential interest in the use of percarbonate in place of perborate," says Merluzzi, although sodium percarbonate is now mainly used as a bleach booster in all-fabric bleaches. Sodium percarbonate has traditionally not been able to compete in this market because it is less stable than perborate.

However, Merluzzi says, "FMC has developed technology for a stable percarbonate to respond to the industry's needs." Degussa, too, says it has "successfully obtained coated percarbonates that have storage stabilities in detergent formulations comparable to perborates," according to Wardell. "And we are currently working to improve percarbonate bulk handling characteristics."

Although peroxygen chemicals effectively boost detergent cleaning power, they are limited in that they require moderate wash temperatures of at least 60 °C to achieve reasonable bleaching rates. Recognizing this, companies are "looking at new low-temperature bleaching systems for the long-term future," says Solvay Interox's Parker. "There is no doubt that, with the changes envisaged in wash temperature, machine design, and energy conservation, the search for even lower temperature performing products will increase," he says.

Some R&D efforts are focused at designing bleach activators that transform peroxide into organic peracids, which oxidize and decolorize stained matter,

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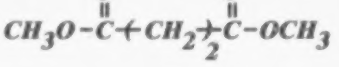

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imparting a brightening effect. Degussa, for one, is working on low-temperature bleach activators based on renewable raw materials.

Enzyme use increasing

The proliferation of peroxygen-based bleach additives in detergents has improved the market for detergent enzymes. The use of enzymes in laundry products had been limited because enzymes become deactiviated by chlorine bleach. Detergents with perborate bleach, with which enzymes are compatible, have allowed consumers to bypass chlorine bleaches. Solving this problem has been one of the factors that has encouraged a steady increase in the use of enzymes in detergents.

"The detergent enzyme segment of our business continued to expand in 1993," observes Thomas Meyaard, a product manager at Elkhart, Ind.-based Solvay Enzymes, which produces alkaline proteases for use in laundry detergents and a protease amylase combination product for use in detergent or automatic dishwasher applications.

Indeed, because enzymes are compatible with a number of trends in the detergents market, their growth in the future is ensured. In fact, "many products were reformulated in 1993, generally increasing the volume and types of enzymes used," Meyaard adds. For example, Procter & Gamble's Grime notes, "by the nature of their catalytic chemistry, enzymes provide the space-efficient performance that compact detergents require."

"The green movement likely will continue to be a significant factor in this industry, which is good for our business," adds Meyaard. "Enzymes are natural, biodegradable proteins produced through fermentation. They are very compatible with a green movement."

Another trend—consumer demand for multifunctional detergents—will also drive enzyme growth in the detergents market. For example, genetically engineered enzymes are being used increasingly in laundry products to improve color fastness, says Roland W. Kohl of Hampshire Chemical, Lexington, Mass. He adds that Hampshire—a producer of a nitrilotriacetic acid trisodium salt used as a detergent builder and of specialty surfactants—is also developing proprietary substances that would work in concert with enzymes to address the color-fastness problem.

As ingredient suppliers work to develop new types of enzymes, bleaches, and other additives that perform better in powder concentrates and the newer and fast-growing liquid detergent products, ICI Surfactants is attacking the market from another angle. The company is promoting its Aquaperle concentrated nonaqueous liquid laundry detergent formulation, which is the only liquid that can support the addition of perborate bleaches, according to Lee Richards, detergents market manager for ICI Surfactants, Wilmington, Del.

The polyethylene-glycol-based Aquaperle is four times more active than conventional powders, uses one third the chemicals, and requires 70% less packaging while providing comparable wash performance.

U.K.-based parent ICI is already producing commercial quantities of an Aquaperle formulation tailored to European wash conditions; the product was launched in Europe between 1990 and 1991. As a next step, over the past year, the company has been developing formulas for U.S. wash conditions.

"We think we have a decent shot at putting the first commercial [Aquaperle-based] product on the market in the U.S. in 1994," says Richards. The industry's move from powder compacts to concentrated liquids that contain as little as 35% water "works right into our hands," Richards adds. Aquaperle could represent the next step in this evolution: an even more concentrated nonaqueous liquid that can be more highly loaded with additives.

Fillers and reformulation

Although ICI warmly greets the move toward compact detergents, producers of detergent fillers such as sodium sulfate are hoping that trend will lose momentum. Before environmentally minded consumers began to demand concentrated detergents in less packaging, consumers believed that "bigger was better" and the "big box" ruled the market, reminisces Bill Rigney, marketing manager for sodium sulfate for the minerals products division of Philadelphia-based Elf Atochem North America.

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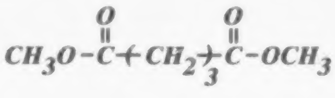

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The typical laundry powder was formulated with about 35% sodium sulfate filler to add bulk to the detergent and fill that box, notes Rigney. In contrast, today's concentrated detergents contain no more than 10% sodium sulfate and some products contain none. As a result, consumption of sodium sulfate by the U.S. detergent industry has dropped as much as 40% since 1992, Rigney notes.

However, sodium sulfate will not be shut out of the detergent industry entirely, he predicts. For one thing, sodium sulfate is not just used in laundry powders—it is also used in dish powders, a market in which concentrated products do not yet dominate.

And even in the laundry market, sodium sulfate still has a place, he says. Besides acting as a filler in laundry detergent formulations, sodium sulfate acts as a flow aid, dispersing active ingredients "so they don't end up in one sock," for instance, says Rigney.

"And the big box has not gone away," Rigney says. He points out that after concentrates took over the Japanese market in the late 1980s, traditional detergents later regained a significant share. In the U.S., the move to concentrates "has leveled off and we may just see traditional detergents regain some market share here." Some consumers are turned off or confused by concentrates' costing more per ounce than traditional detergents. "They are not completely convinced that they are getting more bang for their buck," he comments.

The fabric softener market has also been affected by the trend toward concentrated products. Producers of fabric softeners face the same public pressure to mimimize plastic waste. Concentrated liquid fabric softener products, which in the U.S. represent 55% of the market (with tumble dryer sheets representing 45%), contain higher active ingredient levels today than they did seven years ago and are sold in packages that reduce waste, according to Uwe Sebold, a researcher with Akzo Chemicals' detergents and surfactants unit, Duren, Germany.

Environmental pressures have also forced the fabric softener industry to look for replacement materials for dihydrogenated tallow dimethyl ammonium chloride (DHTDMAC)—the classic softener active ingredient. Today, volumes of DHTDMAC used in Europe have declined by more than 70% and in the U.S. by more than 20% in recent years, says Sebold. In Europe the primary substitutes are esterquats, which biodegrade more rapidly than does DHTDMAC and are less toxic to aquatic organisms, he observes. In North America, replacements are mainly imidazolines and amidoamine quats, allowing formulation of higher active concentrates in conjunction with DHTDMAC.

The market for soda ash has also been challenged by the environmentally conscious move to concentrates. In detergents, soda ash simultaneously functions as a builder, agglomerating agent, surfactant carrier, and an alkaline source. The trend toward compact household laundry detergents has forced the industry to focus increasingly on the granulation technology used to make these products, according to William Breunig, FMC's marketing manager for soda ash.

To keep up with detergent makers' needs in formulating and developing compact home laundry detergent powders, FMC supplies several different soda ash products of varying densities and absorptivities. The company's technical service department in Princeton, which has a team dedicated to the detergent industry, has been working on improving soda ash products.

Soda ash sales to the domestic detergent market were down slightly for 1993 versus 1992 because heavy-duty liquid laundry detergents gained share against powders during 1993, observed Breunig. He says that the powder-to-liquid ratio fluctuates from year to year and may have changed from 60% powder–40% liquid to 55%–45% for 1993. "The swing in powder-to-liquid detergent sales had an impact on soda ash demand," he says; "but we anticipate that 1994 will be a strong year in terms of worldwide demand for soda ash. With the continued shutdown of synthetic capacity, demand for natural soda ash from the U.S. will continue to grow."

Breunig adds that the switch to liquid laundry detergents does have an upside for FMC because it requires the use of more sodium sesquicarbonate, a buffering agent for liquid detergent systems, including laundry, automatic dishwash-

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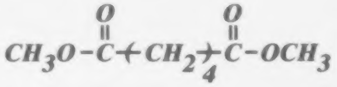

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ing, and institutional and industrial detergents.

The overall market for U.S. soda ash in 1993 is estimated in excess of 10 million tons. Domestic consumption of soda ash is about 7 million tons, and consumption of soda ash by the cleaning compounds industry represents approximately 12% of that figure, according to FMC. Exports of soda ash are expected to exceed 3.2 million tons for 1993.

International markets

Increasingly, ingredient suppliers must think about exporting their products or producing them outside the U.S. Because the big U.S. soap and detergent producers are operating on a more global scale, they "are requiring a global supply capability," says Witco's Ackerman. With its recent Schering A.G. acquisition, she continues, "Witco is now positioned very well to provide product on a global basis. Efforts to find ways of producing exactly the same type of product with the same specifications and quality characteristics at multiple locations around the world continue."

In addition to meeting their customers' demands for more global formulations, U.S. ingredient suppliers are also looking to outside markets to help them fend off any lingering effects of the poor U.S. economy and to recoup the investments they have made in technology. "Opportunities outside the U.S. and Europe continue to be encouraging and may supplement any downturns we see in our more established markets," says Ackerman. Indeed, developing countries, such as those in South America, offer particularly good growth potential for detergent chemicals throughout the rest of this decade, say many ingredient suppliers.

For example, "improving economic conditions, including widespread privatization, increasing consumer purchasing power, and growing foreign investment make South America one of the most promising regions in the world for surfactant growth," according to Don Carswell, manager of Latin American research at Houston & Associates.

In addition to the growth in demand that goes hand-in-hand with improving standards of living, developing countries are often an outlet for ingredients such as phosphates that have fallen out of favor in the U.S. Indeed, "the outlook for phosphates in home laundry detergents outside the U.S. is very good, particularly in Latin America," according to FMC's Carfagno. He notes that the home laundry detergents marketed in Latin America are typical of the conventional formulations sold for many years in the U.S.

"Phosphates continue to be used in home laundry detergents in countries such as Mexico, based on the inherent cost and performance benefits of STPP over other builder systems," says FMC's Furman. The Mexican market for phosphates in home laundry detergents is attractive to FMC because the company can efficiently transport material from its low-cost, 450 million-lb-per-year STPP plant in Green River, Wyo. The passage of the North American Free Trade Agreement, he expects, will help solidify the Green River plant as a long-term source of phosphates for this market.

Although the outlook for phosphates in Latin America is good, many ingredients that are no longer used in the U.S. are likely to be phased out of developing countries, too. Thus, opportunities abound for detergent ingredient suppliers who can position themselves to take advantage of reformulation trends that usually lag those in the U.S.

In South America, for example, surfactant markets will grow quickly—not only in volume terms owing to the improving standard of living, Carswell says. "The dollar value per unit volume will grow even more rapidly, as branched alkylbenzenes are replaced by LAB and other, more sophisticated surfactants."

LABs are expected to replace the less biodegradable branched alkylbenzenes in South America by 1995, according to Carswell. Most companies in Colombia changed to the use of LABs in 1993 and Peruvian producers are expected to change over in 1994. This will leave only minor markets in South America, such as Ecuador and Bolivia, as branched alkylbenzene consumers, he adds.

Producers of linear α-olefins, which can be used to make LABs, may also

Continued on page 58

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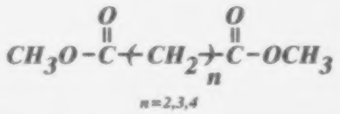

$$CH_3O-\overset{O}{\overset{\|}{C}}\left(CH_2\right)_n\overset{O}{\overset{\|}{C}}-OCH_3$$

$n=2,3,4$

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Continued from page 55

benefit from this trend. Demand for these raw materials is up not only in South America, but also in the Philippines and Indonesia, where detergent producers are just now converting from branched alkylbenzene-based surfactants, explains C. Eric Spore, an α-olefins product specialist at Chevron Chemical, Houston.

Environmental standards will inevitably become more consistent worldwide as the industry moves toward a global marketplace, says Douglas R. Wright, president of environmental affairs at Colgate-Palmolive, New York City. "The chemistry in detergent formulations will be scrutinized more than ever," he adds. "We [in the detergent industry] have an obligation to assure everyone, including ourselves, that our formulations are indeed environmentally compatible."

Recognizing this, the detergent industry and its suppliers have been working to gain a more sophisticated understanding of the environmental impact of their products. The Soap & Detergent Association (SDA), which represents roughly 135 soap and detergent manufacturers and raw material suppliers, is committed to remaining "a technically driven association dedicated to research that develops accurate and reliable information about the human and environmental safety of the industry's products," according to Gerald R. Pflug, SDA's president.

As part of this movement, the industry has begun to judge the environmental friendliness of each of its ingredients not just by looking at the raw materials from which it was made, but by analyzing its entire life cycle from production to disposal, says Spore. The public has given detergent products that are based on petrochemicals a bad name. Consumers have gravitated toward products made from oleochemical feedstocks such as coconut oil.

However, "looking at the entire life cycle of each type of product, you see that, from an environmental standpoint, there are advantages to petrochemical-based products," says Spore.

Solvay Interox photo

Concentrated home laundry powders have been rising in popularity.

Oleochemicals are derived from plants, which must be fertilized, creating runoff that may not always be good for the environment. And these chemicals must be processed the same way petrochemicals are to get a detergent ingredient, such as lauryl sulfate, for example, Spore adds.

Armed with a more sophisticated understanding of how their products affect the environment, detergent and ingredient suppliers are making a concerted effort to better educate both consumers and regulators so that future decisions might be based more on sound science rather than on emotion. Research, says Pflug, is "the cornerstone of SDA's efforts to avert or correct the unnecessary regulation of cleaning products, their ingredients, and their packaging."

For example, SDA applauds the Federal Trade Commission's (FTC) ruling in July 1992 that claims of environmental terms and labels used in marketing various soap and detergent products should always be backed by competent and reliable evidence. Through this ruling, the FTC supported SDA members' "long-standing practice of providing useful and fact-based environmental information about its products and packaging," says Pflug.

The public, too, seems to be better informed. The environmental movement, "while it is having a tremendous impact on the soap and detergent industry as a whole, has quieted down a bit," observes Texaco Chemical's Borland. "In the future, any kind of attention to this issue will be much more rational," she predicts. "Consumers and regulators will be relying more on cold, hard statistics as they realize that this issue can't be driven by emotion."

Indeed, addressing the environmental issues surrounding soap and detergent products is just one of many challenges that raw material suppliers must face in today's marketplace. "Competitive pressures faced by the detergent industry in 1994 will create mounting demand for new raw materials that can enhance product effectiveness, satisfy a variety of regulatory requirements, and address the economic needs of suppliers and consumers," according to Ken Schoene, director of performance chemicals for BASF, Parsippany, N.J.

"Success in the evolving market will increasingly depend on the effective utilization of multipurpose raw materials such as surfactants, polymers, and other agents capable of global application," says Schoene. "As research, development, and product distribution all become progressively more global, the need for suppliers to provide timely and innovative technical support becomes particularly important."

The industry's demands on raw material suppliers are not likely to let up soon. In order to meet future marketplace requirements, "the emphasis must be on chemistry or chemical technology," says Procter & Gamble's Grime. "The days of 20-year lifetimes for detergent chemicals are gone forever," he predicts. "Another period of dynamic change is just around the corner."

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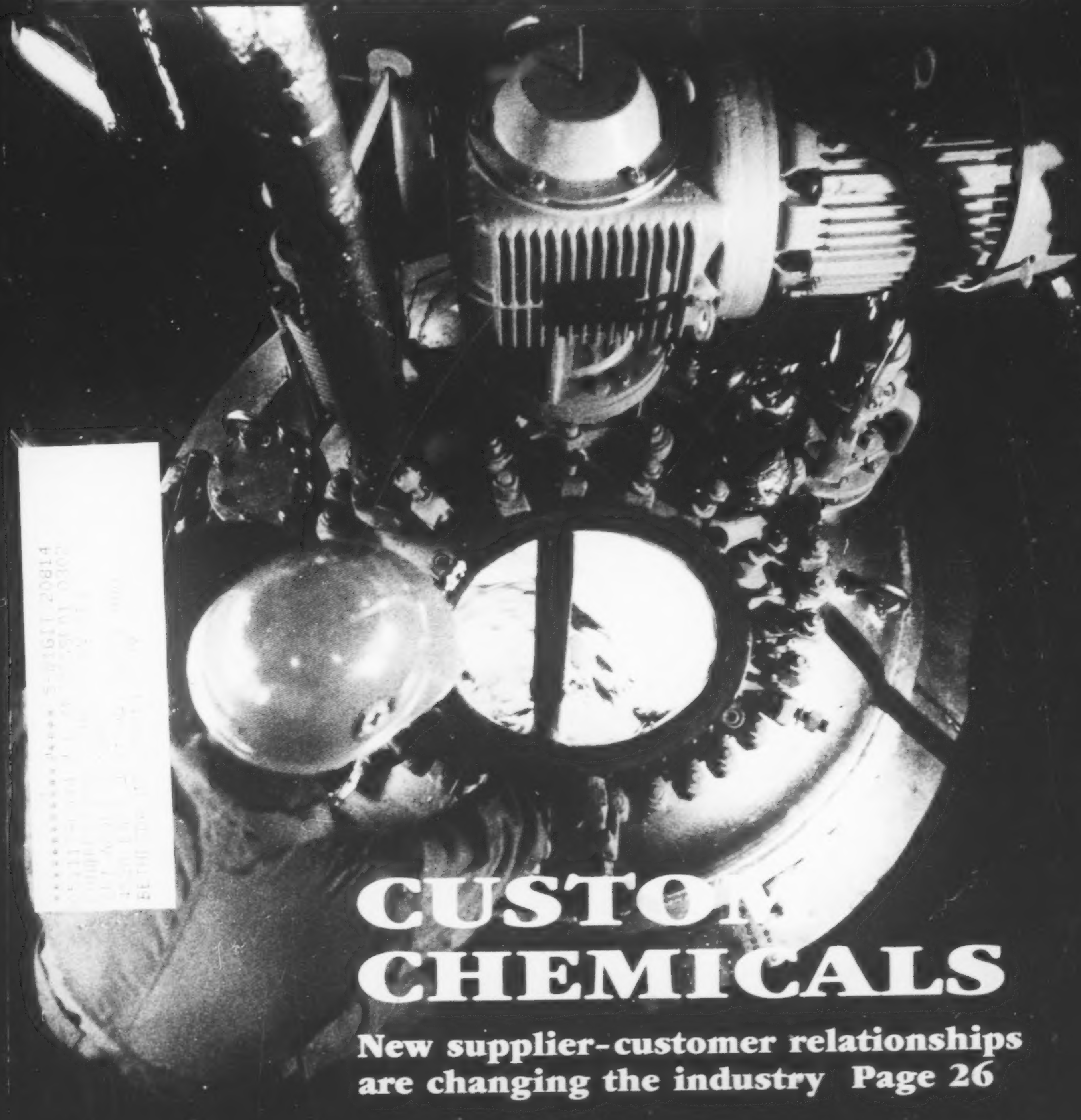
CHEMICAL & ENGINEERING NEWS

C&EN

JANUARY 31, 1994

ROLE OF ESTROGEN MIMICS IN THE ENVIRONMENT PROBED PAGE 19



CUSTOM CHEMICALS

New supplier-customer relationships are changing the industry Page 26

CHEMICAL & ENGINEERING NEWS
C&EN
JANUARY 31, 1994

NEWS OF THE WEEK

- Plutonium from dismantled nuclear weapons presents a clear danger, says a National Academy of Sciences panel that urges immediate attention to prevent risks. **Page 6**
- Fourth-quarter 1993 chemical earnings show dramatic increases over year-earlier figures, continuing a trend that includes no overall improvement in sales. **Page 7**
- German chemists develop a simple, inexpensive method for making dihydroxyacetone phosphate, and reacting it at once with aldehydes to make unusual sugar derivatives. **Page 8**
- NIH forum will help agency draft guidelines for academic research sponsored by industry and government—encouraging technology transfer while protecting taxpayers' investment. **Page 8**
- Russian chemist is jailed after refusing to attend trial on charges of revealing chemical weapons information. **Page 9**
- EPA announces plans to fund more than 70 projects under Administration's Environmental Technology Initiative, including program with industry to develop new hazardous waste cleanup technology. **Page 9**

COVER: Worker charges reactor for custom project at Salsbury Chemicals, Charles City, Iowa

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BUSINESS

Use of acrylic resins is forecast to increase steadily through 1997, bolstered by recovering U.S. economy and the compounds' wide range of markets and end uses. **Page 13**

GOVERNMENT

EPA's list of toxic chemicals that could be accidentally released enables communities to plan for risk management, but it shows little coordination with OSHA's list of hazards. **Page 16**

President's blue-ribbon advisory panel on sustainable development met in Seattle to learn from Northwest Pacific citizens who have been pursuing innovative strategies. **Page 17**

SCIENCE/TECHNOLOGY

Research links man-made mimics of estrogen to reproductive abnormalities and cancer in humans and wildlife; evidence on risks to humans is fragmentary but suggestive and worrisome. **Page 19**

EDUCATION

NSF has awarded 14 planning grants to groups developing proposals to reform undergraduate chemistry curricula. **Page 25**

PRODUCT REPORT

The custom chemicals industry, which serves drug, agrochemical, and other companies, is confronting new market forces that are pushing more suppliers and customers into long-term relationships. Page 26

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Editor: Michael Heylin (202) 872-4501
Managing Editor: Madeleine Jacobs
Assistant Managing Editors: James H. Krieger, Janice R. Long, Rebecca L. Rawls, Donald J. Soisson, William J. Storck
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LETTERS

Chemists have become watchers

Why starting salaries of B.S. chemical engineers are 40% higher than those of chemists, the question addressed by Ted Logan (C&EN, Jan. 10, page 3), recalled the aphorism that goes: There are three kinds of people—those who make things happen, those who watch things happen, and those who don't know that anything is happening.

The earmark of the engineer is design. Thus, the culture of the engineer falls in the first category. It's been said that culture derives from the ancient guilds, artisans who made things.

Not so long ago the earmark of the chemist was synthesis. That culture, too, is in the first category. But the paradigm has been shifting, some say from alchemist to a sort of priesthood searching for a Holy Grail called scientific truth.

That paradigm shift plus the growing fascination with analysis and mathematical modeling has relegated chemists to the second category, that of watchers. Campus chemistry has become a spectator sport, more concerned with what is than with what can be.

In part that shift is due to the ease with which analytical data can be generated and published, especially when each announcement is trumpeted as a threat to the public's health. In part it's due to academic emphasis on problems that offer neat solutions. But today those are the trivial ones, divorced from what the public sees as important enough to pay for directly. So, enter the government that's there to help you. Its funneling of money into universities without benefit of free-market testing has corrupted the world view of chemistry faculty and their students.

Once, academic chemists made and taught the theory that their students were willing to pay to learn and that they made things for public use, as opposed to agency use. In both cases, they quickly learned the discipline of the marketplace. That refining process has been lost as chemistry faculty members have been more and more influenced by political and emotional forces.

Solution? Let's shift our educational focus from finding and introducing tools for which we hope to find (or never find) uses, to supplying tools to make good things happen. To do that we have to decide, first, what we want B.S. chemists to do. Here's my short list: materials behavior, that is designing (that engineer's word) structure for function; marketing in all its fascinating aspects from market research to packaging to global sourcing and sales; chemistry-based law from regulatory to intellectual property management; and biological chemistry from toxicology and epidemiology to prosthesis and dose-delivery design.

I can hear the shrieks from campus already: "But that's not chemistry!" To which my response is, "If chemical professionals don't prepare people for these tasks, who will?" Twenty-five years ago I wrote, "We are teaching students to play checkers with virtuosity when society wants them to play chess." We're still doing that except now it's world-class chess they want us to play.

Benjamin J. Luberoff
Summit, N.J.

Supporting minority scientists

I read with displeasure the letter by Kip Kimbrough titled "Why train more scientists?" (C&EN, Dec. 13, 1993, page 5). The writer appears to have misconstrued the National Science Foundation's reason for spearheading a drive aimed at producing more minority science graduates by the year 2000.

The number of minority science graduates in this country is at an all-time low. If the job market is flooded with scientists, minority scientists are certainly not the cause.

Kimbrough's letter further seems to suggest that chemistry programs should be shut down or that the graduation rate of chemists ought to be attenuated in order for employed chemists to retain their jobs. These, in my opinion are incongruous.

I find the NSF goal to be quite reputable. The idea is esteemed by many except for a few like Kimbrough who fail to apprehend the need for minority presence in all facets of science and technology.

Despite downsizing, layoffs, and belt-tightening by chemical and pharmaceutical companies, all of my colleagues who completed their degrees over the past six months are employed and delighted with their jobs. Some had four job offers.

We need to motivate people from mi-

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Steady Growth for Acrylic Resins Consumption Projected Through 1997

■ ***Projected upsurge in U.S. economy will spur growth in acrylic resins use of 5% per year between 1992 and 1997***

As the U.S. economy continues to recover, use of acrylic resins will rise from almost 2.2 billion lb in 1992 to 2.7 billion lb in 1997, according to a new study from industry consultant firm Freedonia Group. The study, "Acrylic Resins to 1997," projects that U.S. acrylic resin consumption will increase almost 5% annually during that period, up from 3% per year for the previous five years.

Improvements in the economy will stimulate consumption of acrylic resins in a host of markets and end uses including plastics modifiers, construction materials, adhesives, and paints and coatings, says William Baumgartner, an analyst with Freedonia. However, Baumgartner's new 157-page report notes use of acrylic resins will also rise because they allow manufacturers to formulate more "environmentally friendly" products.

Because acrylic resins may be suspended in water, they are ideal substitutes for traditional solventborne alkyds that are used, for instance, to formulate paints and coatings. As the more traditional solventborne alkyd paints and coatings dry, they release volatile organic compounds, contributors to the formation of atmospheric smog.

Government regulatory pressure has forced paints and coatings formulators to severely cut down on the use of solvents. In many cases, formulators have moved to alternative technologies—among them waterborne acrylics—in order to reduce solvent content in paints and coatings to the absolute minimum. Only some small paint segments have until now resisted the change to waterborne acrylics. Other opportunities do exist for acrylics to replace some solvents, such as in adhesives.

Baumgartner's study divides acrylic resins into two broad categories: acrylates, which accounted for 46% (or 1 billion lb) of acrylics consumption in 1992; and methacrylates, which accounted for the other 54% (or 1.2 billion lb) of acrylics consumption. Of the two classifications, Baumgartner projects that use of methacrylates will grow nearly 5% per year through 1997 and use of acrylates will grow at just over 4% per year.

As the construction market improves in the economic recovery that most economists are predicting for the next few years, demand for use of methacrylates in products such as glazing, building panels, lighting components, and plumbing parts will expand rapidly. Similarly, spiraling growth in the industrial/commercial category will raise methacrylate use in such products as industrial safety shields and signs.

A growing market for acrylates as polyolefin property modifiers and as a comonomer in specialty ethylene polymers will broaden use of acrylates in plastics production, says Baumgartner. Markets are also growing for acrylates in the manufacture of acrylic pressure-sensitive adhesives, especially for packaging applications, he adds.

In a breakdown of demand for acrylics by market and end use, the Freedonia study projects that industrial/commercial use of acrylic sheet for industrial safety barriers and signs will grow 8% annually between 1992 and 1997 to 175 million lb—faster than any other major market. In his study, Baumgartner points out that consumption of acrylic resins in the industrial/commercial segment actually declined 4% between 1987 and 1992.

The study does not discuss reasons for the earlier decline in this segment. But industry sources cite the slow economy and competitive pressure from polycarbonate for the decline. However, the study suggests that improvements in acrylic demand in the industrial/commercial category between 1992 and 1997 will be largely the result of a pickup in industrial equipment orders and a concomitant increase in demand for the safety barriers and face shields required by the Occupational Safety & Health Administration.

Rohm and Haas, ICI, and Cyro Industries, the three dominant vertically integrated producers of methyl methacrylate and acrylic sheet, could benefit if Baumgartner's predictions for the industrial/commercial segment growth materialize. Other markets that employ acrylic sheet and that may grow at or above the 5% annual average for all acrylic resins between 1992 and 1997 are construction materials (up 5%) and transportation (up

Industrial, consumer markets to pace U.S. acrylic resins growth

Millions of lb	1992	1997	% annual change 1992–97
Paints & coatings	669	795	4%
Construction	303	387	5
Textiles & fibers	233	288	4
Plastics modifiers	184	240	6
Adhesives & sealants	157	198	5
Transportation	123	165	6
Industrial/commercial	119	175	8
Paper binders	90	110	4
Consumer	48	70	8
Other markets[a]	229	267	3
TOTAL ACRYLIC RESINS	**2,155**	**2,695**	**5%**

a Includes printing inks, furniture polishes, water treatment polymers, and polymer concretes. **Source:** Freedonia Group

—CIRCLE 18 ON READER SERVICE CARD

6%), including aircraft windows and boat shields. The growth rates are particularly significant for the potential profitability of ICI's July 1993 acquisition of three DuPont methyl methacrylate and acrylic sheet plants.

Growing demand for appliances, medical devices, data storage media, eye wear, and even dental fillings will push acrylic resin consumption up almost 8% per year to 70 million lb by 1997 in the consumer category, notes Baumgartner. Growth in the category, however, is from a rather small base of 48 million lb in 1992 compared with the 669 million lb Baumgartner says the paints and coatings market consumed in 1992.

The nearly 4% annual growth in consumption that Baumgartner predicts for paints and coatings is lower than the average 5% annual growth for all acrylic resins between 1992 and 1997. But the absolute increase of 126 million lb for paints and coatings is certainly much greater than the 22 million lb growth in the consumer category over the same period. So although growth in acrylic resins consumption in paints and coatings may appear to be below average, continued demand for waterborne and environmentally safer paints will mean that paints and coatings will continue to claim almost one third of acrylic resins consumption.

Other markets for which the study forecasts growth rates lower than the 5% average for all acrylic resins are paper (up 4% to 110 million lb), textiles and fibers (up 4% to 288 million lb), and the mixed bag of smaller "other markets" (up 3% annually between 1992 and 1997 to 267 million lb).

Mature markets for acrylic resins in printing inks, furniture polish, and polymer concretes will account for the below average growth in the study's other markets category. Use of acrylic resins as paper binders is also a fairly mature end use. It, too, will grow more slowly than the overall market for acrylic resins.

Acrylic resins used to produce acrylic fibers, chiefly for textile use, are a different matter. Acrylic fiber production has been on the downswing for a number of years. DuPont, for instance, shut down its 200 million-lb-per-year acrylic fiber capacity in 1990, leaving only Monsanto and Cytec as principal producers.

The study projects that acrylic fiber will continue to lose market share to other fibers such as cotton in the production of active wear and fleece, and wool in the production of sweaters. Other textile uses for acrylic resins are mostly slow-growing mature markets. They include use of acrylic resins as backing for curtain and drapery fabrics, and as binder for insulating fiberfill.

Copies of the study, "Acrylic Resins to 1997," are available from Freedonia Group, 3570 Warrensville Center Rd., Suite 201, Cleveland, Ohio 44122-5226. The cost is $2,600.

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CUSTOM CHEMICALS

Move toward long-term supplier-customer relationships is changing industry's face

Stephen C. Stinson,
C&EN Northeast
News Bureau

Driven by needs to cut costs and raise operating efficiencies, drug companies worldwide are turning more than ever to custom chemical producers to supplement or replace their own manufacturing. This is an important trend, because drug companies have historically taken the biggest share of custom chemical production. The agrochemical industry, the second largest client of custom producers, is under many of the same pressures.

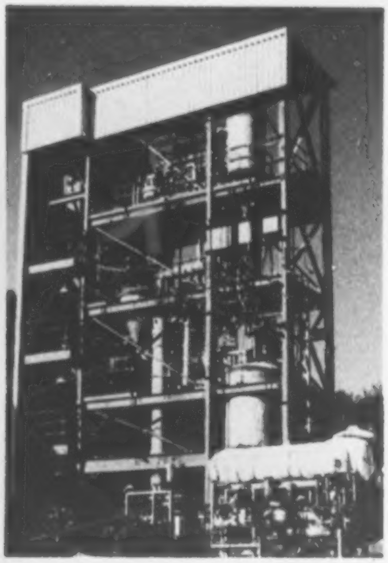
Yet at the same time, the fine chemicals industry, which furnishes custom production to the drug, agrochemical, and other specialty chemical industries, is in the midst of a profound metamorphosis. Wide-ranging shifts in ownership of fine chemical facilities are changing the landscape of custom production. In addition, the U.S. in particular is the focus of new custom production marketing campaigns by consortia of fine chemical firms in the U.K., Eastern Europe, and former Soviet republics.

Consultant Enrico T. Polastro of Arthur D. Little International in Brussels, outlines the pressures on the drug industry. First, he says, the patterns and philosophies of health care are changing. Second, governments are cracking down on costs of drugs and are openly hostile to the research-oriented drug firms. Third, regulatory agencies are raising the heights of hurdles regarding drug approval, production process specifications, environmental protection, and worker safety. Fourth, life cycles of products are growing shorter as delays in product approval and registration erode patent lives, and competitors are getting ever better at coming up with "me-too" products. And finally, the drug companies' own shareholders are growing more demanding and impatient. Many of these same pressures afflict the agrochemical, food additive, flavor and fragrance, and dyes segments of the fine chemicals industry, which are also customers for contract chemical production.

To Polastro, cutting costs and increasing efficiencies to meet these pressures lead logically to an examination of manufacturing. In particular, specialty chemical companies of all kinds should revise their manufacturing stances to the broader policy of "sourcing," he says. In a total sourcing policy, in-house manufacturing becomes only one option for procuring intermediates and active ingredients.

Among factors that mitigate against in-house fine chemical production, Polastro cites the disproportionate amount of capital that production capacity consumes. In addition, the true strategic functions of drug, agrochemical, and other specialty chemical companies are research, development, and marketing, he maintains, not manufacturing. Polastro also points to in-house manufacture—as it is now done—as riddled with pockets of inefficiency, leaving plenty of room for improvement. Increasing environmental hurdles also make in-house production a burden. And there is no logic to in-house production when so much custom chemical production capacity is available at outside firms.

Specialty chemical firms seem to be only too aware of these factors and are decreasing their reliance on in-house production and using more custom production. Between custom producers and their clients, there is an evolution toward what the custom producers call partnership, which is a long-term one-on-one relationship. Marc New, director of pharmaceutical fine chemicals for Lonza in Basel, Switzerland, traced this evolution in remarks to attendees at ChemSpec Europe '93 in Basel, Switzerland.



ChemDesign plant in Fitchburg, Mass., exemplifies advanced equipment and environmental safeguards needed at a modern custom production plant. Clockwise from above: Location of plant next to Leominster State Forest demands environmental concern; reactor from Swiss firm Buss enables safe hydrogenations; chiller uses liquid nitrogen to condense volatiles from air coming from all vessels; water treatment plant converts waste to inorganic salts for disposal; sales vice president William Scott indicates vent that goes from each vessel to the chiller.

New (pronounced Nef) notes that in the past there have been two opposing chemical marketing stances: one customer-many suppliers and one supplier-many customers. An example of one customer-many suppliers was Smith Kline & French's H2 antihistamine ulcer drug, cimetidine. When it first introduced the drug, Smith Kline marshaled an array of custom producers to make cimetidine. Everyone, including Lonza, seemed to be doing something for cimetidine—an intermediate or a reaction step.

But New suggests that such a situation might never recur. This is because of the increasing complexity of drug molecules and the desires of drug companies for rapid and secure production arrangements.

Complex molecules often require new chemical technologies that only a few firms can afford to perfect and maintain. Instruments for increasingly sophisticated analyses and specifications of quality are also costly. Security of supply means that custom producers must prove themselves able to comply with environmental regulations, including those for waste management. Drug companies cannot afford links to suppliers that may be shut down for environmental reasons. New thus sees an evolution toward partnerships as opposed to "buying." In buying, a customer qualifies several suppliers and stimulates competition on price. A partnership would be a close, thoroughgoing, long-term relationship between a drug company and one or two suppliers.

New's example of one supplier-many customers is Lonza itself. He cites the company's 2-aminothiazole-4-acetic acid derivatives, which are attached as side chains to newer cephalosporin antibiotics of many drug firms. Though each thiazole side chain may be slightly different, they all come from Lonza's "tree" of such structurally related compounds.

New, however, sees an evolution away from this situation and toward partnerships. This is because drug companies are moving away from research to discover me-too compounds. Finding just one more cephalosporin or angiotensin-converting enzyme (ACE) inhibitor for high blood pressure is not as attractive as discovering an antiobesity or anti-Alzheimer's agent. The cost of R&D to discover and market a me-too drug is about the same as that for a new drug type. But the me-too drugs will enter a heavily competitive market in which the drug company is unlikely to recover the cost of R&D.

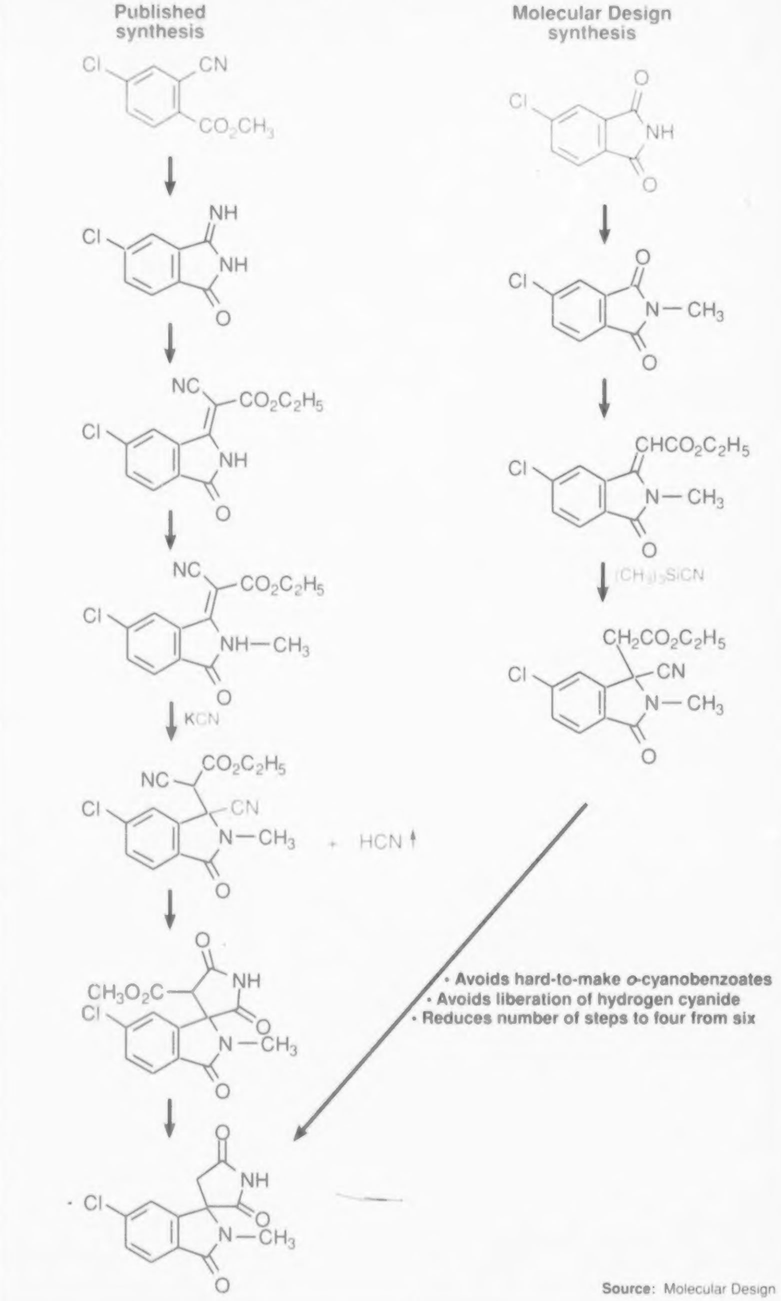
The only exception New sees to this trend away from the one supplier-many customers situation is in producing generic versions of drugs going off patent. This is because the generics industry is price-driven, and partnerships and customer loyalties are nonexistent. This situation leads to a shakeout among suppliers, leaving the one with the most environmentally friendly and cost-efficient process to supply many generic drug houses. New cites the Hoechst process for the anti-inflammatory agent ibuprofen as an example.

Supplying a $12.5 billion market

The dollar value of custom chemical production is hard to gauge. Client companies do not disclose much for fear of giving information to competitors. In addition, custom producers are bound by secrecy agreements. And analysts disagree on what and how much to count.

For example, some producers take a proprietary raw material from a client, perform one or a few synthetic reactions on it (tolling), and send the product back to the client. Should these producers claim the whole value of the product at that point as their "sales"? Or should they be limited to some estimated value of what they added themselves? And what of a standard intermediate in someone's catalog that has only one buyer one year? Is that intermediate now "custom-produced"? And does "manufacture" include physical processes as well as chemical reactions?

Databases can help improve synthetic schemes



- Avoids hard-to-make *o*-cyanobenzoates
- Avoids liberation of hydrogen cyanide
- Reduces number of steps to four from six

Source: Molecular Design

Bearing all these caveats in mind, analyst Jean-Charles Pasquier of the consulting firm Eurekem Conseil in Courbevoie, France, puts the worldwide value of custom chemical production at $12.5 billion. About 600 producers employ 45,000 people, he says in his recent study of the subject. The U.S. and Europe account for 400 of these firms.

For his part, to show how estimates can vary, Polastro of A. D. Little puts the value of the entire world fine chemicals market at between $26 billion and as much as $34 billion. This represents only intermediate compounds or bulk active ingredients. It does not include costs of administration, sales, R&D, formulation, packaging, or profit, which all appear in the price of the finished product. Polastro's estimates are lower than those of many other analysts, and he ascribes this to the small proportion of the cost of fine chemicals in the prices of finished products.

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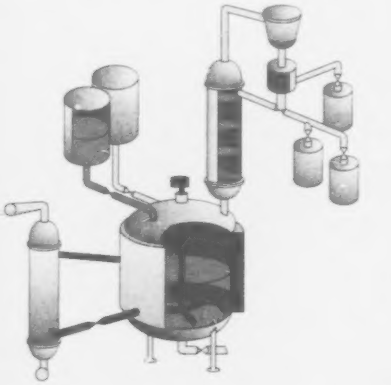

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He breaks down the value of fine chemicals production—custom, merchant, and captive—into $7 billion to $9 billion for the U.S., $12 to $15 billion for Europe, $6 billion to $7 billion for Japan, and $1 billion to $3 billion for the rest of the world. Polastro cites the U.S., Europe, and Japan, "the triad," as the fine chemicals leaders. He has argued that there may be a strong trend under way to transfer fine chemicals production from the triad to such places as China, India, and Southeast Asia.

Within fine chemicals worldwide, Polastro assigns $15 billion to $17 billion worth to the drug industry. Of that amount, 40% is produced by drug firms for their captive use, and 60% is sold by fine chemicals companies to drug firms on the merchant market. Of the merchant market, $2 billion to $3 billion worth is custom produced. Dollar sales of fine chemicals for drugs are growing 4 to 5% annually, Polastro says.

Pesticides account for $5 billion to $7 billion worth of fine chemicals, growing at 2 to 3% per year, the Brussels analyst estimates, 40% in the merchant market, and $300 million to $500 million custom-produced. The amount of fine chemicals that are custom-produced for such end uses as food additives, flavors and fragrances, and dyes is smaller than the amount for drugs and pesticides and is too hard to pin down exactly, Polastro says.

Food additives represent a $1.5 billion to $2 billion fine chemicals market, increasing 2 to 3% yearly, and 50% are merchant sales. Flavors and fragrances are also a $1.5 billion to $2 billion fine chemicals market, growing 2 to 3% per year, and 50% are merchant sales. Dyes use $1 billion to $2 billion worth of fine chemicals, annual growth rates are 1 to 2%, and 40% of that is merchant sales. The fine chemicals market trails off into a collection of miscellanies worth $2 billion to $3 billion, growing at 2 to 3% per year. Even the proportion of merchant versus captive sales is impossible to estimate in this portion of the market.

Eurekem Conseil's Pasquier notes a regional influence on attitudes toward buying and selling custom production services. On the issue of buying a compound or making it in house, he says, "If the U.S. groups are already in favor of the 'buy' attitude, it is not yet the case in Europe. Most European phar-

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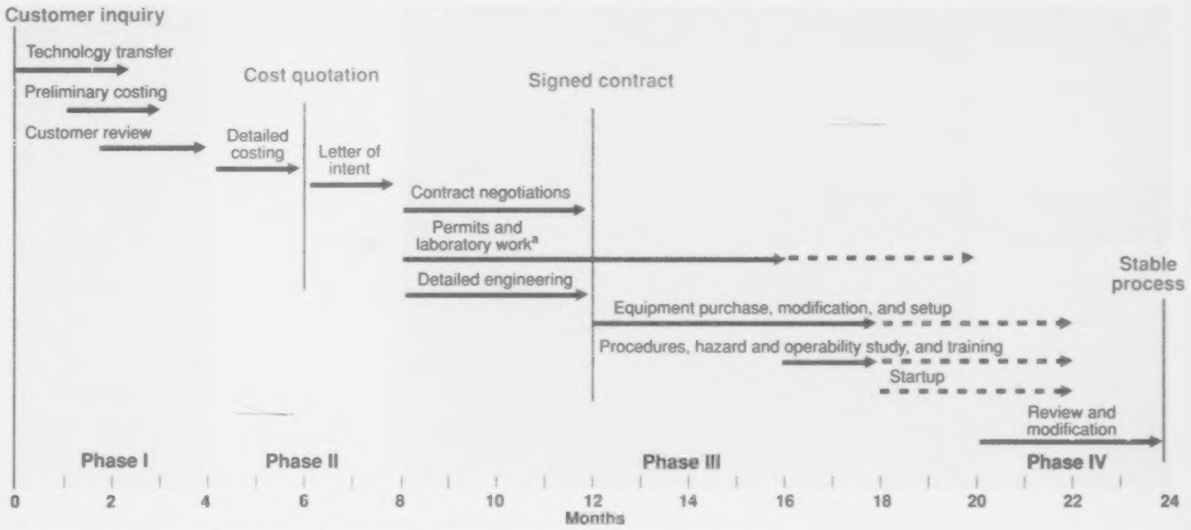
Though custom producers can respond in a week, production may not start for 18 months



[a] Regulatory permits may be speeded up because agencies are familiar with company performance. **Source:** Ruetgers-Nease

maceutical groups were always pharmaceutical companies. This is one of the reasons why [in-house] production is more frequent in Europe. There is, however, a gradual change in attitude, and the European market for contract manufacturing is expected to develop in the near future."

In noting other regional differences, Pasquier says that custom chemical production companies in the U.K. are active and well organized among trade associations, and well known throughout the world. The activity of these British companies shows up in their recently launched campaign, "North America Now," which aims at publicizing their expertise on the North American continent.

Of the two dozen or so French companies, he says that they "are less known abroad. The customer approaching these companies has the impression that the business is organized like a private club with high entry barriers for new members."

The Italian fine chemicals industry is very advanced, he says, but has evolved along a different direction. Weak protection for patents in Italy has led to an extensive industry to make standard intermediates and generic active ingredients, but only little activity in custom production. "As a result," Pasquier says, "Italy is not a very important country for contract manufacturing in Europe, in spite of the fact that its fine chemicals industry is much more developed than in [some] other European countries."

Ironically, Germany is also underrepresented in custom production. "When compared with the U.K. or France, one would expect to find about 60 companies in this business in Germany. In fact, only 12 companies have been identified.

"It is somewhat difficult to explain this situation," he says. "The general opinion is that the large German chemical groups have enough production facilities available to manufacture [the chemicals] themselves. This explanation, however, is not satisfactory, since if it is economically justified for other Western groups to subcontract production during the launching period of a new product, it should also be attractive for a German group.

"On the other hand, large chemical groups are present in neighboring Switzerland, and contract manufacturing activities are very developed there."

An industry in flux

Easily the most spectacular event in the ongoing reconfiguration of the custom synthesis industry has been the fragmentation of MTM's chemical empire. Headquartered in Yarm, England, MTM (which once stood for Marlborough Technical Management) spent the 1980s weaving together a fabric of chemical companies, several of which were American and several of which engaged in custom production. Falling on hard times, MTM began the 1990s by selling off these companies to pay down debt.

The first U.S. firm out of the MTM fold was Farchan Laboratories, Gainesville~~, Fla.~~, in a management buyout led by president and original founder John Cochran. Farchan has specialized expertise and equipment to make acetylene and organosilane derivatives.

And Jack Dickstein, founder of both Dajac Laboratories and Monomer Polymer Corp., Southampton, Pa., was able to buy back Dajac from MTM in 1991 and Monomer Polymer in 1993. The reconstructed firm has been named Monomer Polymer & Dajac Laboratories, and Dickstein is moving the headquarters to Feasterville, Pa.

Other pieces of MTM were bought up by BTP (which once stood for British Tar Products), Manchester, England. Indeed, it was from BTP that Dickstein redeemed Monomer Polymer Corp. Other MTM units obtained by BTP include Lancaster Synthesis of Windham, N.H., and Morecamb, England; and Hardwicke Chemical Co., Elgin, S.C. BTP also got the now defunct Fairfield Chemical Co. from MTM, combined part of it with Lancaster Synthesis, and closed the Fairfield plant in Blythewood, S.C.

International Specialty Products (ISP), Wayne, N.J., purchased MTM's plant and fine chemicals business in Colum-

Directories help buyers choose among the hundreds of prospective sellers

People seeking contract chemical production can find providers of such services in several directories. For example, the Custom Synthesis & Custom Manufacture section of the American Chemical Society's "Chemcyclopedia" gives five- to 15-line listings of 165 firms with summaries of the capabilities of each. The current 1994 edition is available from ACS, Sales & Distribution Department, 1155—16th St., N.W., Washington, D.C. 20036, at a cost of $60.

Brandon Associates has published the 1994 edition of "The Brandon Guide to Custom Synthesis Services—North America," which sells for $190. The book gives one-page entries for 350 companies, cross-indexed by 200 chemical processes. The entries include equipment and processes available; details of pollution control, waste management, and analytical instrumentation; and whether the plant is approved by the Food & Drug Administration. Also available is the 1993 edition of a European guide to 300 companies for $225. Both books may be ordered from Brandon Associates, P.O. Box 1244, Merrimack, N.H. 03054.

Custom Guide Co. has published the latest, ninth, edition of "Custom Processing Services," which sells for $300. It gives one-page entries for almost 300 companies and is in looseleaf format so users can make their own additions; the price includes future supplements. One index lists 25 unit operations and 130 chemical reactions and a second index lists plant locations. Users new to buying custom production can compile a list according to capabilities and then visit those companies that are closest. The directory may be ordered from Custom Guide, P.O. Box 358, Closter, N.J. 07624.

Quest Data's "A Guide to Custom Chemical Manufacturing & Processing" has multiple-page entries for each of 425 North American, European, and Japanese companies. In addition to equipment and processes available, a list of catalog chemicals produced is given. Entries include provisions for pollution control and waste disposal, analytical instruments available, and FDA approvals. The guide can be ordered for $135 from Quest, P.O. Box 210288, Nashville, Tenn. 37221. The price includes three updates at six-month intervals.

The Synthetic Organic Chemical Manufacturers Association has published its "1993/94 Commercial Guide," which lists its 125 member companies that do custom production. The capsule entries list contacts, equipment available, reaction capabilities, and details of analytical and waste disposal. The price of the guide is $25 and it is available from SOCMA, P.O. Box 79106, Baltimore, Md. 21279.

The directory chapter of Eurekem Conseil's "Contract Manufacturing in the Fine Chemical Industry" gives one-page entries for each of 350 U.S. and European firms. Included are lists of processes and equipment available; numbers of employees; FDA or ISO 9000 certifications; names of contacts; and telephone, telex, and fax numbers. The 640-page book also has a business overview chapter and one-page descriptions of 180 reactions used in contract manufacture. The study is available for $1,650 from S.E.T.E., 5 Rue Jules Lefebvre, 75009 Paris, France.

bus, Ohio, once known as Orsynex. ISP, in turn, is the recently founded, publicly owned company set up for the purpose of owning the chemicals business of privately held GAF Corp.

Besides the atomization of MTM, other significant events in the custom synthesis industry have included the divestitures of the chemical businesses of American Cyanamid, Eastman Kodak, Outokumpu (the Finnish metals and natural resources firm), and W. R. Grace.

Cyanamid set up its fine chemicals business as Cytec Industries, headquartered in West Paterson, N.J., and distributed shares in the new company to its own shareholders at the rate of one Cytec share for every seven Cyanamid shares held. Outokumpu sold its holdings in OM Group in a public offering. The Finnish company had assembled that metal salts producer company from Mooney Chemicals, Cleveland; Outokumpu Chemicals, Kokkola, Finland; and Vasset, Ezanville, France.

Managers of Grace's organics division bought their company and named it Hampshire Chemical Corp. Based in Lexington, Mass., Hampshire includes the former Grace organic and polymer divisions, Evans Chemetics, and Grace Rexolin of London, England.

Elsewhere in custom chemical production, Zeeland Chemicals, Zeeland, Mich., formerly owned by Hexcel, has become part of the Cambrex Corp. family of companies. Freedom Group has acquired Hilton Davis Co. of Cincinnati from PMC. In addition, Catalytica has bought a fine chemicals plant from Sandoz Agro in East Palo Alto, Calif. This is Catalytica's first producing facility, which it will use partly for custom production.

Sepracor is another company that has bought its first producing plant. The firm acquired Pharmaglobe, near Halifax, Nova Scotia. And United Chemical Technologies (UCT) has bought the specialty silanes and silicones business and plant in Bristol, Pa., from Hüls America. A coming change is the intended sale by Exxon of its Callaway Chemical Co., Columbus, Ga., a water treatment, paper, and textile chemical firm that also offers custom production.

Changes of ownership from MTM to BTP seem to have benefited the component firms involved. Vice president James Guy of Lancaster Synthesis in Windham, N.H., says his operation has stronger financial backing under BTP. For now, Lancaster has no plant in the U.S. but produces in Kirkby, England. The company does custom production on a scale of 500 g to 500 kg. Guy says that Lancaster may build a plant in the U.S. in 1995 or 1996.

Lancaster's Kirkby plant includes advanced environmental protection and safety features of the type that have become commonplace among modern custom producers. The production area is completely isolated from the sewer, and all effluents and washings from processes are placed in drums and shipped to an approved disposal company. This lets the company use heavy metals such as mercury, chromium, and manganese with the assurance that residues will be disposed of responsibly. Off-gases from vessels and plant air at Kirkby are scrubbed before emission from the building.

Among Lancaster's chemistry strengths are butyllithium reactions, alkali metal reductions, Grignard reactions in tetrahydrofuran, and brominations, alone or in conjunction with hydrogen peroxide, phosphorus trichloride, triphenylphosphine, or mercuric oxide (Hunsdiecker reaction). Process strengths include sublimation, molecular distillation of unstable compounds, and reactions carried out at –10 °C.

Hardwicke of Elgin, S.C., is an additional beneficiary of BTP's financial strength, according to marketing manager Joseph G. Mancini Jr. Hardwicke's principal expertise lies in continuous brominations, Friedel-Crafts reactions with aluminum chloride on a large scale, Grignard reactions, and a variation on the Ullmann reaction, in which acetal-protected aromatic bromoaldehydes are coupled with potassium phenoxides to form diaryl ether derivatives. Hardwicke has arrangements with other firms to purchase its hydrogen bromide and aluminum salt by-products.

And the former MTM fine chemicals business and plant in Columbus, Ohio, is thriving under ISP ownership. Paul D. Taylor, who is general manager of ISP Fine Chemicals, says the parent has made new investment available to ensure continued compliance with state, federal, and Food & Drug Administration regulations.

Among new purchases for the Columbus facility are improved process controls and analytical instrumentation. Also available is support from the parent research, process engineering, and analytical laboratories in Wayne, N.J. (Taylor came to his new post from heading process engineering in Wayne.) It is also helpful to the new custom synthesis side of the business that ISP is already known to the drug industry as a maker of excipients (formulating additives).

At the newly independent Eastman Chemical, operations including custom production are centered in Kingsport, Tenn., and Batesville, Ark. The new company is no longer linked to Sterling Organics or to the laboratory chemical business as it was under Kodak.

Kodak sold the laboratory chemical business to Fisher Scientific. Fisher has also bought the laboratory chemical company Janssen Chimica, Beerse, Belgium. Janssen Chimica was part of Janssen Pharmaceutica, which in turn is a subsidiary of Johnson & Johnson of the U.S.

Dollar sales are about 20% smaller at Eastman than when Eastman was under Kodak, but production capacity is

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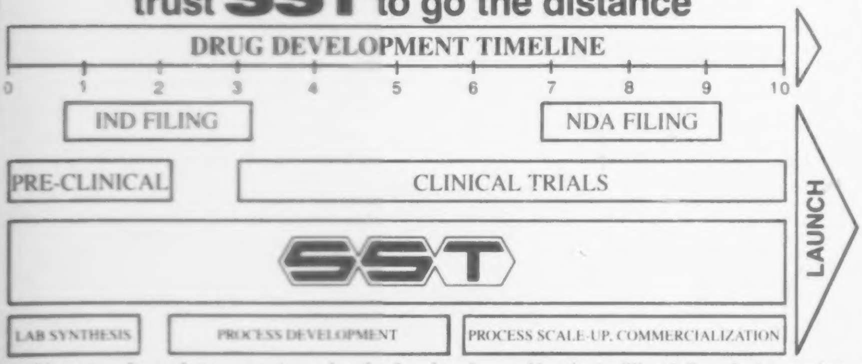

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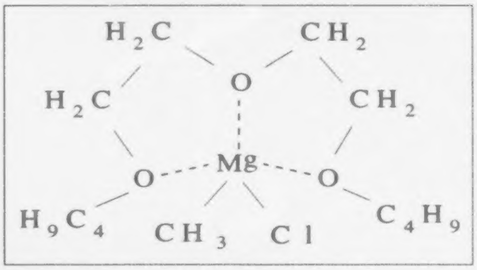

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$(n\text{-}C_4H_9)_4P(CH_3CO_2)\text{-}(CH_3CO_2H)$	Tetrabutylphosphonium Acetate, Monoacetic Acid	17786-43-5
$(n\text{-}C_8H_{17})_4PBr$	Tetraoctylphosphonium Bromide	23906-97-0
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PRODUCT REPORT

Survey identifies causes of chemical plant accidents

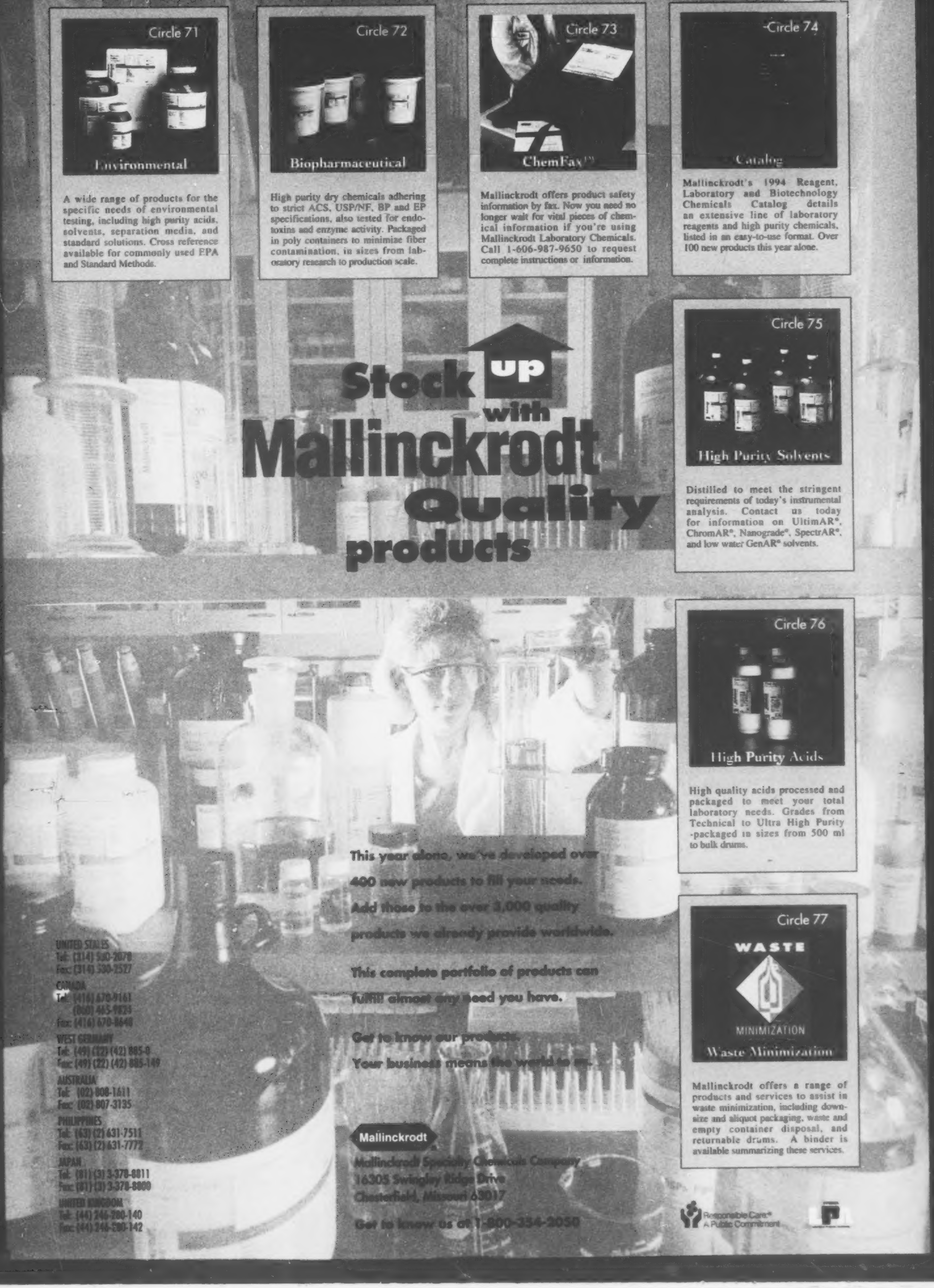
Process	% of incidents[a]
Polymerization	48%
Nitration	11
Sulfonation	10
Hydrolysis	7
Salt formation	6
Halogenation	6
Friedel-Crafts	4
Amination	3
Diazotization	3
Oxidation	2
Esterification	1

a Accidents surveyed 1962–87; percents do not add up to 100% because of rounding. **Source:** *Chem. Eng. Res. Des.*, **67**, 381 (1989)

about the same. R. L. (Bob) Morrow, who is vice president and general manager for fine chemicals, says the company will be at a short-term disadvantage owing to the loss of its tie with the laboratory chemicals production plant in Rochester, N.Y. That facility has equipment ranging from 22-L glass flasks to 500-gal reactors for production of small amounts. Morrow says plans are under way to install similar capacity at Eastman. However, he says, Eastman learned a great deal about the custom marketplace and client relations during the relationship with Sterling Organics and the reagent business. Eastman intends to apply those lessons as it ventures out on its own.

At Zeeland, the inclusion under the Cambrex umbrella has meant that Zeeland can take advantage of raw materials, farming out production steps, and technical advice from the other subsidiaries. James K. Datson, business development manager, says Zeeland's own strengths are in resolution of racemic mixtures by classical, diastereomeric crystallization, high-pressure synthesis of amines by reaction of other amines with aldehydes or ketones (reductive alkylation), and production of quaternary ammonium compounds.

Zeeland also can send ammoxidations (reactions with ammonia to make nitriles) to sister company Nepera in Harriman, N.Y. Zeeland has a cost advantage in buying pyridine derivatives from Nepera to use to make advanced intermediates for drugs against the human immunodeficiency virus (HIV). And Zeeland can call on sister



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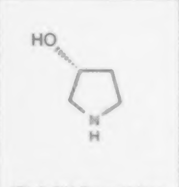

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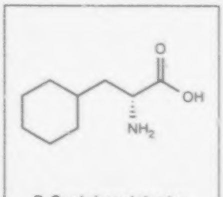

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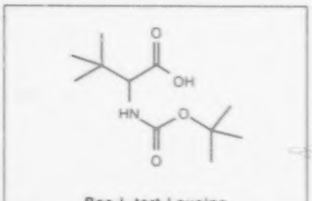

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companies for technical consultation when developing new processes at Zeeland.

The first client for the plant that Sandoz Agro sold to Catalytica will be Sandoz itself. Sandoz had been making ethyl and propargyl esters of 3,7,11-trimethyl-2*E*,4*E*-docosadienoic acid and the isopropyl ester of the 11-methoxy-acid in this plant as insect growth regulators and the housefly attractant 9*E*-tricosene. Catalytica will make these for Sandoz.

But Catalytica's big custom production thrust in East Palo Alto will be toward the drug industry. Catalytica managers say drug companies will be attracted by the firm's expertise in chemical process development generally and by its track record in catalytic processes for pollution abatement and cleaner catalytic production of known, useful intermediates.

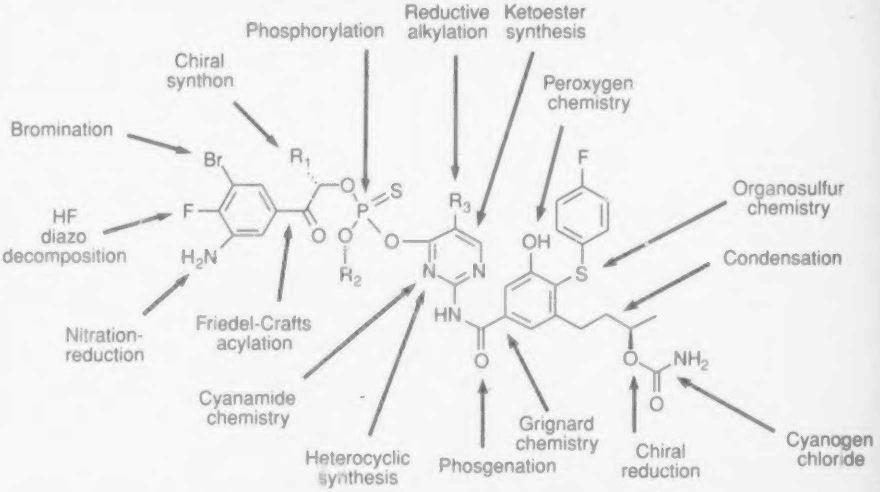
For example, Catalytica has developed processes for oxidation of ethylene to acetaldehyde without chlorine cocatalysts; of 2,6-diisopropylnaphthalene to 2,6-dihydroxynaphthalene, 2,6-naphthalenedicarboxylic acid, and 6-hydroxy-2-naphthoic acid with zeolite catalysts; of *m*-diisopropylbenzene to resorcinol; of phenol to catechol; and of spent hydrogen bromide to recovered bromine with oxygen as the sole oxidant.

Sepracor will use the Pharmaglobe plant in Nova Scotia to produce enantiomeric drugs for itself and to place special orders for others. The company has licensed both the asymmetric hydroxylation of olefins invented by organic chemistry professor K. Barry Sharpless of Scripps Research Institute and the asymmetric epoxidation of olefins invented by organic chemistry professor Eric N. Jacobsen of Harvard University. Previously, Sepracor had to contract such reactions from companies in Japan.

In another thrust in chiral drugs, Sepracor has studied enantiomers of other companies' racemic drugs, discovered unexpected new activities in them, patented the enantiomers, and offered licenses to drug companies generally. The Pharmaglobe plant will serve to produce these in case licensees contract their custom synthesis back to Sepracor.

Both Catalytica and Sepracor began as chemical technology companies. The idea was that they would discover new products and technologies, patent them, and license the patents. But the thinking in such technology companies has changed as a result of the realization that customers want products rather than technologies. Thus Catalytica and Sepracor are examples of companies that have "backed into" custom chemical production.

Molecules of bulk active ingredients become increasingly complex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F
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P
S
R_3
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O
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R_2
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Condensation
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N
N
HN
Nitration-reduction
Friedel-Crafts acylation
O
O
NH_2
O
Cyanamide chemistry
Grignard chemistry
Cyanogen chloride
Heterocyclic synthesis
Phosgenation
Chiral reduction

Though totally imaginary, this fanciful structure has often been invoked to symbolize the complexity of new products and the array of techniques brought to bear in their custom production.

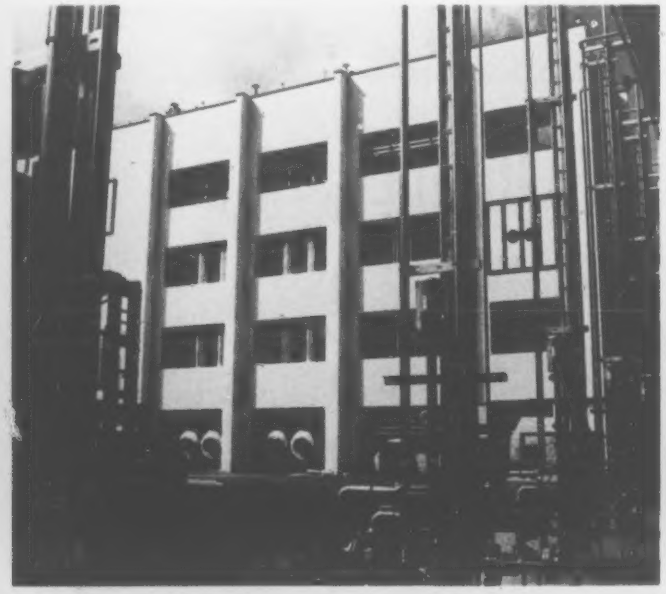
Source: Ian Schott, Lonza

The organosilanes and silicones business and plant that UCT bought from Hüls America is the one-time independent Petrarch Systems. UCT has relocated and consolidated its operations at the Petrarch site in Bristol, Pa. John MacMillan, director of technical sales and service at UCT, says UCT will use the Petrarch name for the recognition that it carries. Typical requests for custom production include experimental aerospace resins to resist damage during atmospheric reentry of space vehicles, high-refractive index materials for fiber optics, and monomolecular compounds for academic research.

The British are coming

The "North America Now" campaign, in which the British custom fine chemicals industry has targeted Canada, the U.S., and Mexico, has just finished its first phase. Representatives of the 10 companies that have assembled under the loosely organized umbrella name UK Fine Chemicals wound up an 11-day tour of the northeastern U.S. in October. They stopped in nine places and gave presentations to a total of 200 people whom they had invited from 32 drug and other specialty chemical companies. Presentations described the collective expertise of the 10 firms. Presentations were followed by mini-trade shows, in which the British companies spread their literature on widely separated tables and invited frank individual discussions about synthetic chemical needs.

The 10 firms that make up UK Fine Chemicals are Boots Chemicals, Nottingham; Contract Chemicals, Prescot, Merseyside; Courtaulds Chemicals, Spondon, Derby; Exchem Industries, Harwich, Essex; Fine Organics (part of Laporte), Middlesbrough, Cleveland; Hickson Fine Chemicals, Castleford, West Yorkshire; A. H. Marks, Wyke, Bradford; Peboc (part of Solvay), Anglesey, Gwynedd, Wales; Robinson Brothers, West Bromwich, West Midlands;



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and Zeneca Fine Chemicals (formerly part of ICI), Blackley, Manchester.

The chemistries emphasized by the 10 firms are amine synthesis, catalytic hydrogenation, chiral synthesis, chloromethylation, cyanation, fluoroaromatic chemistry, Friedel-Crafts reactions, heterocyclic chemistry, nitration, organophosphorus and organosulfur chemistry, peptide synthesis, peroxygen chemistry, and phosgenation. At the final presentations of the tour, Tony W. Bastock, marketing director at Contract Chemicals, singled out British expertise in chiral synthesis and phosgenation for discussion.

Boots Chemicals, Peboc, and Zeneca Fine Chemicals do chiral syntheses. Phosgenations are carried out by Fine Organics, Hickson, and Peboc. Bastock says this illustrates that UK Fine Chemicals is a loose association of mutual competitors and not a cartel. Thus, U.S. companies usually have a choice of British suppliers for the same type of chemistry.

As an example of UK Fine Chemicals' capabilities in chiral chemistry, Bastock cites Boots as a leading producer of (*S*)-ibuprofen. Boots had earlier pioneered in ibuprofen discovery. And Zeneca produces 1,500 metric tons per year of (*S*)-α-chloropropionic acid, an important drug and pesticide intermediate, by enzymatic resolution.

For phosgenation, Bastock says the three purveyors of that service have phosgene generators from the chemical engineering firm of Buss in Pratteln, Switzerland. These generators, located in buildings reserved only for them, are infinitely variable in production rates between a few tens of kilos per hour to several hundred kilos per hour as needed. Thus phosgene is made and used as required, making it unnecessary to buy, make, ship, or store large amounts.

Phosgene is a valuable agent for conversions of acids to acid chlorides, amides to nitriles, primary amines to isocyanates, and alcohols to chloroformates. But its infamy as a war gas has made its responsible use a matter of public concern. The more tractable diphosgene (trichloromethyl chloroformate, $Cl\text{-}CO_2\text{-}CCl_3$) can be used by the three firms as a phosgene substitute in small-scale reactions.

The next phase in the North America Now campaign will be invitations from the 10 British firms to North

American conferees at ChemSpec Europe '94, April 18–21 in Manchester, England, to visit their plants during the trip. Next, the 10 companies will return to the U.S. to exhibit at Chemical Specialities USA '94, Oct. 17–20 in Chicago.

In addition to the British effort, companies have sprung up to market custom chemicals in the U.S. that are to be produced in Eastern Europe. For example, Syntest, a Russian joint stock company in Chernogolovka, near Moscow, offers synthetic services of chemists at 300 academic research institutes in the former Soviet republics. The company also has a U.S. subsidiary, Syntest Princeton, in Princeton, N.J.

In addition, ChemBridge, headquartered in Northbrook, Ill., with offices in Moscow, represents private and state-owned laboratories, pilot plants, and full-scale chemical plants, many formerly military, in the former Soviet republics. And Chemapol USA of Englewood Cliffs, N.J., represents laboratories and plants in both the Czech and Slovak republics.

Marlene Molloy, secretary-treasurer of Syntest Princeton, says the company was formed to earn money to support chemical research at the participating institutes. The institutes can make compounds in amounts from milligrams to kilograms, Molloy says, but are not equipped for commercial-scale production.

Some clients come to Syntest because they want analogs of biologically active compounds that institute chemists have already made. Or clients want an improved or proprietary process to make one of their own compounds.

Molloy cites the example of a U.S. diagnostics firm that wanted a patentable dye invented for a blood test kit. Molloy sent the assignment into the network of institutes and got four responses. One respondent laboratory fulfilled the task so well that the diagnostics firm asked to have the chemist sent to the U.S. to work on site for a few months.

On another occasion, a U.S. agricultural chemical company screened a battery of related compounds for a desired activity, then asked to have a certain analog made that was not in the original lot. The project eventually grew to requests for many analogs. The agrochem company explained to Molloy that making the compounds themselves would have cost a lot more.

According to Pavel Janacek, presi-

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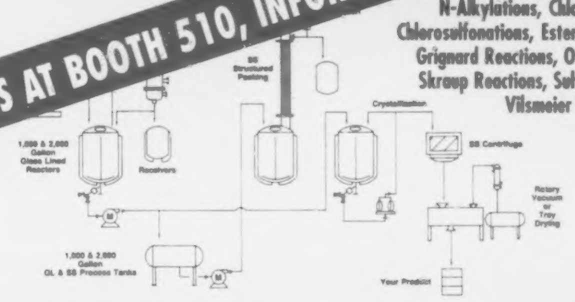
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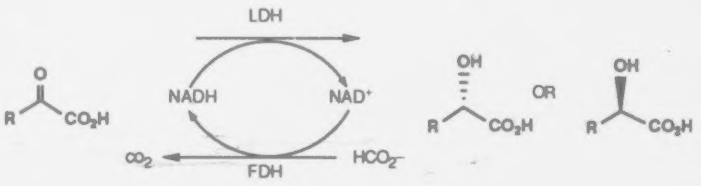

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dent of Chemapol USA, "Chemical and pharmaceutical manufacture is one of the most advanced areas of industry in the Czech and Slovak republics. The stable situation in both countries, low labor costs, a traditionally skilled work force, and a solid R&D base have given Chemapol USA a promising start in the U.S. market."

Janacek says that ailing economies have led to underuse of chemical and drug production capacity in both republics. U.S. clients thus have opportunities to buy custom production by skilled chemists and technicians. Some of the plants are FDA-approved, and others are seeking approval.

Locating a producer

The reconfiguration of the custom chemical producing industry has added to the already inherent difficulties of finding a contract producer, developing a process, and setting a price for a compound that essentially does not exist. That there are a few hundred firms in the U.S. alone promoting their custom services is not much help. Companies looking for custom chemical production can use conventions, directories, and agents to find sources.

Some sources tell C&EN that sessions of the Division of Small Chemical Businesses at national meetings of the American Chemical Society can be useful occasions to make contacts. Perhaps the most important meetings are those called Informex, put on annually by the Synthetic Organic Chemical

Fine chemicals have special characteristics

	Industry segment		
Characteristic	Commodity chemicals	Fine chemicals[a]	Specialty chemicals
Product life cycle	Long (> 30 years)	Moderate	Short (< 10 years)
Product slate	Narrow	Very broad	Very broad
Product volumes	>> 10,000 tons per year	< 10,000 tons per year	Variable
Product price	< $5.00 per kg	> $10 per kg	Variable
Product differentiation	Nonexistent	Low	Very high
Service differentiation	Low	Average	High
Value added	Small	High	Moderate/high
R&D focus	Process improvement	Process development	Product development
Capital intensity	Low	Moderate	High
Customer	Not a chemist	Chemist	Not a chemist

[a] Fine chemicals is the industry segment that is most often concerned with custom synthesis. **Source:** Arthur D. Little

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Manufacturers Association (SOCMA). Informex is the only exposition devoted solely to interests of custom chemical production.

Industry observers tell C&EN that both exhibitors and attendees are "high quality" with respect to fruitfulness of contacts during visits to booths. This is said to be because SOCMA charges fees not only to exhibitors but also to attendees. SOCMA member firms will pay $1,000 per booth and nonmembers $3,500 at the 1994 Informex. Attendees from member firms will pay $250 each and from nonmember firms $350.

Between Informex meetings, there are directories. Ann Hart of Brandon Associates, Merrimack, N.H., which publishes such directories, has a few tips for those making their way through directories and their cross-indexes.

For someone seeking hydrogenation of a nitrile to an amine, she advises, "Pay particular attention to the pressure required for the hydrogenation. Many firms offer low-pressure capabilities, which are not suitable if your compound requires 1,000 psi or greater."

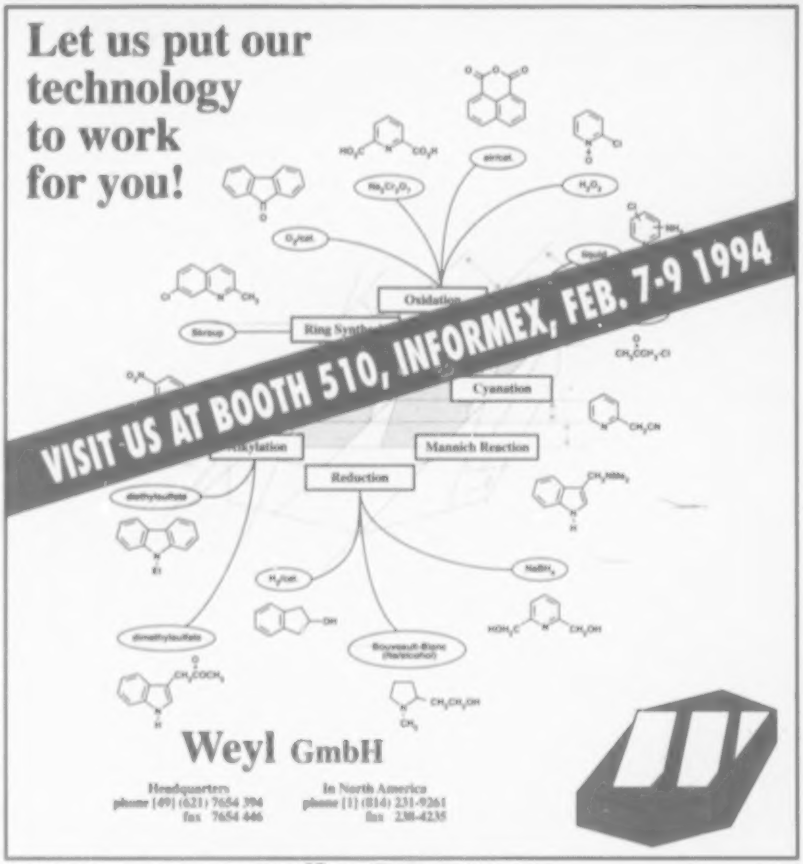
Further, using hydrogenation as an example, "Next, look over their equipment listing for an estimation of the general sizes of their production equipment," Hart says. "Clearly, if you need a million pounds a year, a firm with a 50-gal autoclave won't do.

"If your project requires a special chemical, perhaps one that requires special handling, consult the 'Special Raw Materials' and 'Handle Toxics'? entries of those firms you have identified so far. Consider locale, too, if you believe having a custom producer near you is worthwhile."

In addition to Informex and directories, there are two types of agents one can use. One type represents no particular supplier of custom production and relies on personal contacts to bring a client and suitable supplier together to mediate an agreement. Examples are Richman Chemical, Ambler, Pa., and Sithean Corp., Richmond, Va.

The second type of intermediary represents specific custom producers and becomes an actual part of the project, taking possession of the custom-produced goods and reselling them to the client. Examples are Davos Chemical Corp., Englewood Cliffs, N.J., and Interchem Corp., Paramus, N.J.

Paul Harris, vice president for commercial development at Sithean, says



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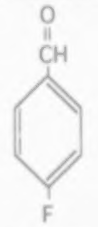
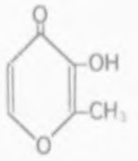
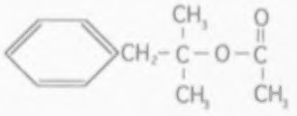
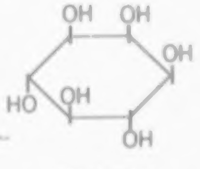
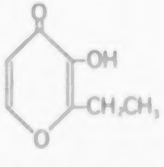
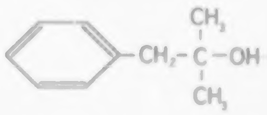

4-Fluorobenzaldehyde


Maltol


Dimethyl Benzyl Carbinyl Acetate


Myo-Inositol


Ethyl Maltol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CIRCLE **41** ON READER SERVICE CARD

Conventions unite contract chemical manufacturers and customers

Three annual conventions have become established in the U.S. to bring together sellers and prospective buyers of custom chemical production. The 9th Annual Informex Trade Show & Technical Symposium will be held this week, Feb. 1–3, in New Orleans. Also, Chemical Specialities USA '94 will meet in Chicago, Oct. 18–20, for its fifth year. And although enantiomers of chiral compounds are only a subset of fine chemicals, Chiral USA '94 to be held in Reston, Va., May 5–6, will be the second U.S. meeting of an annual symposium dealing with producing chiral compounds.

Informex is put on by the Synthetic Organic Chemical Manufacturers Association (SOCMA) and is the only convention devoted solely to custom chemical production. This year's meeting features a technical session and three-day exposition and is expected to draw almost 200 exhibitor firms and 1,000 attendees. The technical session is a panel discussion, "Selecting a Toll Manufacturing Site—The New Criteria."

Next year's Informex will be in Nashville, Feb. 20–22, 1995. For information, contact SOCMA, 1330 Connecticut Ave., N.W., Washington, D.C. 20036; phone (202) 659-0060.

Both Chiral USA '94 and Chemical Specialities USA '94 are organized by Spring Innovations, Stockport, England. For information about either event, in North America contact Brandon Associates, P.O. Box 1244, Merrimack, N.H. 03054; phone (603) 424-2035. Chiral USA '94 consists of 21 papers given over one and a half days on topics including business prospects and government regulation of chiral drugs and pesticides as well as enantioselective reactions and catalysts, biotransformations, resolutions, and auxiliary reagents.

Chemical Specialities USA '94 includes technical sessions over one and a half days as well as a two-day exposition organized by FMJ International Publications, Redhill, England. Industrial chemists, academicians, and consultants will speak at symposium sessions. More than 100 exhibitor firms will be in the exposition, most of whom offer custom production.

most people who come to him have had the function of buying custom chemical production for their companies for only a short time. It may be their first or second such project. These people find Sithean in a directory, or another firm for which Sithean has worked recommends them. Sithean works on commission, which is only paid if the project is completed.

"So you have to get the project at the right place," Harris says. "You have to have a good transfer of information back and forth—sometimes people forget to say something. It's like a marriage. You can't hide things from one another. Also you have to get the project priced right." Harris emphasizes that there is no market that acts to set the price of a project.

Edward Richman, president of Richman Chemical, has also acted as a mediator to bring a customer and a manufacturer together for a commission. But for the most part, Richman Chemical acts as a project manager. As such, Richman subcontracts the project to a manufacturer, bills the customer, and remits to the manufacturer.

This means that Richman is the firm responsible for the project—overseeing it and meeting any problems. This helps in case problems arise and uncertainty exists over whether a purchasing agent, research director, or someone on the business side should handle it.

Project management also helps if the customer and manufacturer have different modes of doing business. For example, the customer may want a price per kilo, but the manufacturer charges per hour of equipment use. Richman can also buy the starting material, relieving the customer company of risk of liability for operations on material it owns. In addition, Richman relates the time dependence of the customer's need for the chemical. Then the company can be sure that the manufacturer will have sufficient lead time to meet the customer's need.

Robert G. Golle, business development manager at Interchem, says his firm represents mostly custom producers overseas, although Interchem does work for Poly Organix of Newburyport, Mass., and Riverside Organics of Detroit. Most of these companies are registered according to good manufacturing practices (GMP) with FDA, or under some form of ISO 9000. Interchem places a project with one of its clients, arranges to bring the compound through customs to the U.S., and handles such paperwork as certificates of analysis and safety data sheets. Golle says staying within Interchem's group of clients helps ensure maintenance of confidentiality.

Dealing from strengths

Once a custom producer has been selected, the client will find that there has been a change from previous modes of doing business. As William T. Scott, sales vice president at ChemDesign Corp., Fitchburg, Mass., puts it, "The 'one-man' operation of the past has been replaced by a group of skilled professionals knowledgeable in the many disciplines that are necessary to run a successful custom chemical operation."

ChemDesign's Fitchburg plant is an example of how custom chemical production must be done today. For one thing, the plant is sited in a scenic wooded area of a populous state. Indeed, the stand of trees is adjacent to and a continuation of the Leominster State Forest, an unforgiving environment.

As part of environmental protection, ChemDesign has installed a liquid nitrogen chiller that receives offgases through ducts from all reactors and vessels in two buildings. All gases are

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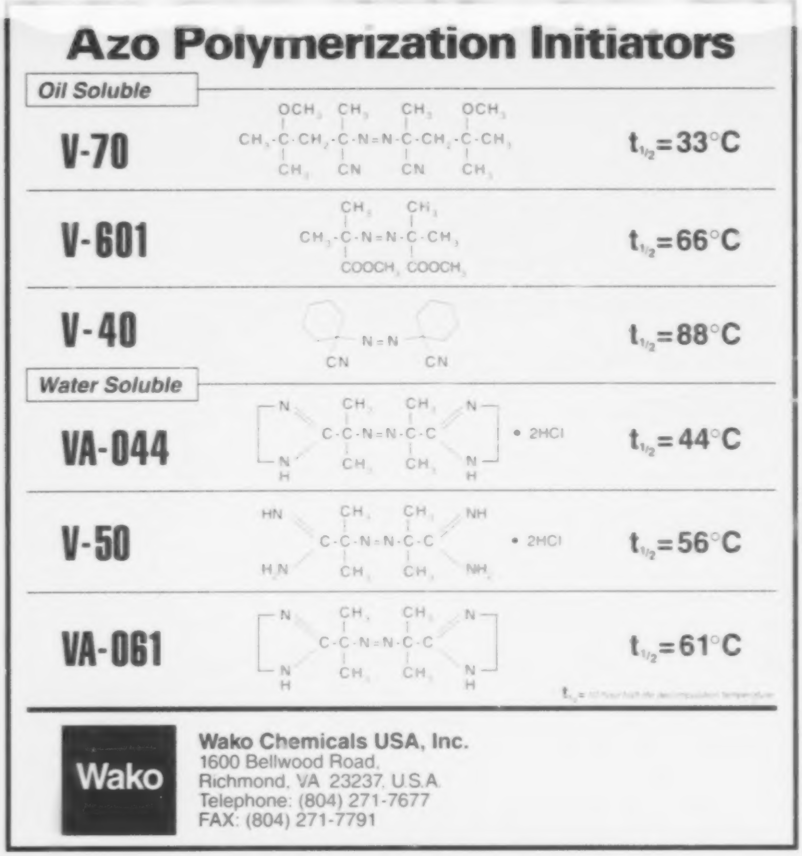
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chilled to -120 °F, which condenses out even such volatile and toxic compounds as methylene chloride. Columns of activated charcoal serve as a "polishing" step afterward.

Condensate from the chiller, together with those waste solvents that are not recycled, goes to companies with permits either to blend them with fuel oil or incinerate them. Airco supplied the original equipment, which was modified by ChemDesign engineers, and today Airco is supplying units based on cooperatively improved designs.

Once any organic compounds are separated from process water, that water goes to a purification plant. This plant separates inorganic salts as a sludge and sends purified water to boilers and cooling towers. Because such units function by boiling and evaporating water, little process water is discharged from the site.

One of ChemDesign's strong suits is high-purity compounds, according to George V. Austin II, who is senior vice president. One type of compound made to special order is diazonaphthoquinones. These are additives to microlithographic photoresists for fabrication of integrated circuits on silicon wafers. Purity requirements are greater for these than for any drug intermediate. In particular, metal contamination must be kept below 100 ppb.

Another recently added strength is a hydrogenation reactor from Buss, the Swiss chemical engineering firm. Such reactors cost $1 million to buy and another $1 million to install, Austin says. But their recirculating loop design ensures especially safe operation, which should give peace of mind to customers as well as to ChemDesign.

But there are limits on what ChemDesign will accept. The company doesn't do phosgenations and air or nitric acid oxidations. Also ruled out is use of such known carcinogens as benzene, and suspected carcinogens are considered carefully. At the end of exhaustive analysis, the company submits a proposal many dozens of pages long to the prospective customer. Each proposal must be signed off by board chairman Richard E. T. Brooks.

Chemie Linz North America also deals from strength, says Nitin Parekh, who is director of new business and technology. The parent company, Chemie Linz of Linz, Austria, is one of the few firms that offer large-scale custom ozonolysis. Other strengths are nitric acid oxidations to carboxylic acids, biocatalytic syntheses and resolutions of alcohols, carboxylic acids, and cyanohydrins. The company carries out the Ritter reaction to make custom acrylamide mononers. It also boasts possession of Buss loop hydrogenation and general purpose reactors.

The strength of Quality Chemical, Jackson, Miss., is partly that of its parent, First Chemical Corp., which, in turn, is a subsidiary of First Mississippi Corp. Carl (Bill) Arnold, marketing manager at Quality Chemical, says this relationship yields the company a steady stream of capital for expansion at its two custom plants in Dayton, Ohio, and Tyrone, Pa. Also, some of the people who do the regulatory paperwork for Quality Chemical are actually on the payroll at First Chemical. And Quality's own R&D staff is supplemented by a much larger laboratory and pilot plant of the parent. Arnold says Quality is thus a small company, like many others devoted solely to custom production. But the company can call on much larger resources. And Quality is free to devote itself to custom production without worries about setting aside production capacity for inhouse products.

At Ruetgers-Nease Corp., State College, Pa., John C. Wetzel says of custom production, "The whole thing is regulations, permits, safety, the environment, being in full compliance, and going through audits." Wetzel, who is technical marketing manager for organic intermediates, points out that the company had no environment, health, and safety department 10 years ago. Then five years ago, one person was assigned that duty. Today the department has a staff of eight.

Indeed, the company has certain technological requirements of customer prospects who bring their processes or new compounds to State College. As to the chemistry, Ruetgers-Nease would like to be told reaction components and conditions, step conversions and yields, simple kinetics, basic thermochemistry, analytical methods used, and product specifications. Concerning the process, customers should describe operating parameters, equipment needs, materials of equipment construction, characterization of wastes, control limits, mass and energy balances, and experience in the customer's pilot plant. Then the company would like to know of any toxicity, fire, or explosion hazards.

Ruetgers-Nease is set up for fast responses to customer queries, Wetzel says. In just two to four weeks, the companies can sign a secrecy agreement, the client can disclose what technology it has, and Ruetgers-Nease can respond with a preliminary cost estimate.

Safe, economical processes

In keeping with the call by Polastro of A. D. Little for cost-effective processes that are safe and environmentally acceptable, a number of tools have been developed to help custom producers achieve this goal. For example, Guenter Grethe, who is director of scientific applications at the office of Molecular Design in Basel, Switzer-

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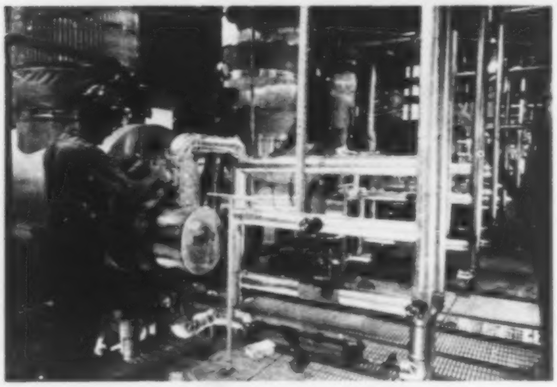

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land, cites uses of his firm's data retrieval programs to seek improved synthetic routes. And chemical engineer Alfred Schnyder of the consulting firm that bears his name in Rieden/Nussbaumen, Switzerland, tells of using reaction calorimetry and differential scanning calorimetry to characterize reactions.

Grethe points to how custom chemical producers can use database computer programs to design improved processes to clients' target compounds, find buyers for excess stocks of intermediates made as parts of previous custom orders, and identify reagents to add to the firm's line of permanent specialties. He cites the example of a series of spirosuccinimides that were found by medicinal chemists at Wyeth-Ayerst Laboratories to inhibit the enzyme aldose reductase. This enzyme reduces glucose to sorbitol, which is thought to accumulate and cause complications of diabetes.

The published syntheses [*J. Med. Chem.*, **35,** 4613 (1992)] each took six steps beginning with substituted *o*-cyanobenzoate esters. These starting materials had to be made by four different routes, depending on the substituents. And one of the six steps liberated hydrogen cyanide.

Grethe has shown how Molecular Design's reaction retrieval systems allow design of a sequence that has only four steps, begins from more easily accessible substituted phthalimides, and eliminates generation of toxic by-products. Reduction of the number of steps alone from six to four makes the method cheaper. But it also reduces the number of wastewater streams to be treated, which further lowers the cost and enhances environmental acceptability.

In addition, one of the four new steps uses trimethylsilyl cyanide. If a producer were to make trimethylsilyl cyanide as a part of custom manufacture of spirosuccinimides, the reagent could be added to the company's catalog for sales to others.

Grethe also gives the example of a producer who may have made some substituted difluorobenzenes as part of an earlier custom order. A search through Molecular Design's Drug Data Report program would turn up two U.S.-approved difluoroquinolone antibacterials plus 16 more under development that use these intermediates. Companies involved in producing these quinolones

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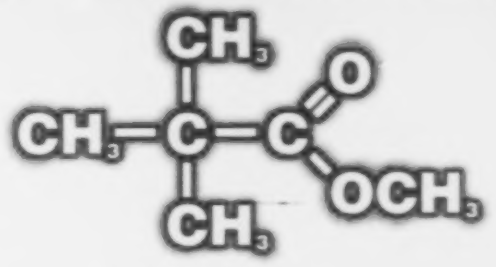

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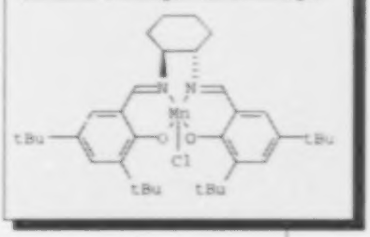

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might be customer prospects for the surplus difluorobenzenes.

After the custom producer or client has made the synthetic sequence as efficient and "user and environmentally friendly" as possible, each step must be examined to determine if it represents a stable process. Engineering consultant Schnyder cites a study of heat-triggered explosions in chemical plants between 1962 and 1987 that pointed to several causes, including insufficient knowledge of process chemistry and thermochemistry, incorrect process management, poorly trained workers, and improperly designed cooling, monitoring, and safety systems.

He analyzes the nature of fine chemicals production to show why heat-triggered explosions are much to be feared in the multipurpose plants used to do custom manufacture. First, the reactions tend to assemble larger molecules from smaller ones. This means that the entropy is decreased. For the free energy of such reactions to be favorable overall, there must be a large enthalpy of reaction. Thus these reactions will generate considerable heat. Indeed, almost half of the thermal explosions in the 1962–87 survey occurred during polymerizations. Schnyder points out that stirring and crystallization are also processes that can generate heat.

Second, Schnyder says, the starting materials of fine chemicals production have a lot of free enthalpy, so they are very reactive. This means that the desired reaction is almost always accompanied by side reactions and such subsequent reactions as decomposition. Decomposition can become autocatalytic (self-sustaining, out-of-control) in reaction mixtures that overheat.

Third, the reaction temperature reported by the research group to the production team is usually based only on the noted influence of reaction temperature on product quality. Researchers may not have considered whether that temperature is commensurate with process stability on a large scale.

Fourth, the batch nature of custom production operations make temperature controllable only by the cooling system. In semibatch work, one reactant is added gradually, and temperature may also be controlled by the rate of dosing.

Fifth, custom producers are usually under pressures of time and efficiency of equipment use. This means that they will strive for the most concentrated reaction mixtures. But concentrated reaction mixtures are the ones most likely to alter greatly in thermal characteristics as the reaction proceeds.

A reaction could run away if done under conditions where it is inherently unstable. For example, Schnyder points out that rate of heat generation increases exponentially with reaction temperature. Thus a graph of heat generation versus temperature curves sharply upward. But rate of heat removal is a

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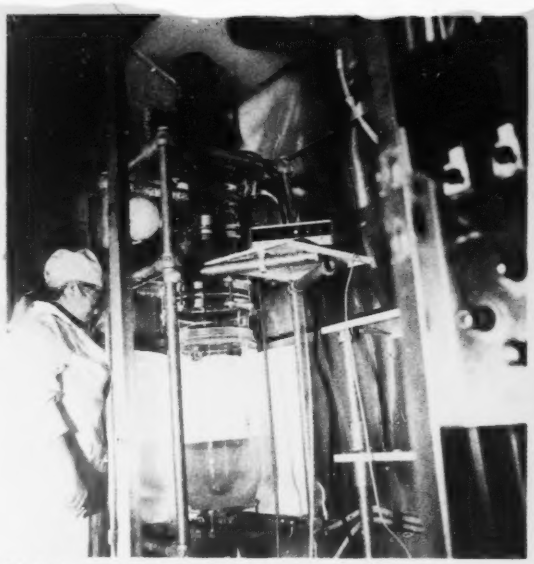

Technican at Russian Cardiology Scientific Center, Moscow, produces an intermediate to special order for U.S. company under contract from ChemBridge Corp.

linear function of temperature difference between reaction mixture and coolant. So a graph of that function is a straight line. The straight line intersects the curved trace at two reaction temperatures, lower and upper, where rate of heat generation equals rate of removal.

If the reaction is run at the lower temperature, and if a disturbance causes a temperature rise, rate of heat removal will exceed that of generation, and the temperature will subside back to the original value. These are stable conditions. But if the reaction is run at the upper temperature, a temperature increase leads to an excursion, and there is nothing that plant operators can do to regain control.

A crisis could also develop if stirring or coolant flow stops. The question is whether the reaction continues, heat builds up, and a decomposition reaction sets in; or whether the reaction stops because operators stop adding reactant.

Schnyder recommends designing the process to be as close to dose-controlled as possible. The reaction rate should be faster than the dosing rate so that the added reactant is consumed at once. Then in case of emergency, no excess reactant would continue to contribute to heat buildup.

Ironically, operating at too low a temperature also can lead to a runaway reaction. This is because reaction rate increases or decreases with temperature. At too low a temperature, the reaction is too slow, and dosed reactant may accumulate. Schnyder advocates use of reaction calorimetry and differential scanning calorimetry to characterize processes intended for scaleup.

Schnyder's firm provides such analyses for companies too small to do them themselves. The need for such information is recognized. For example, Ruetgers-Nease lists "simple kinetics" and "basic thermochemistry" among points of information required of clients when clients' own technology is to be used. ☐

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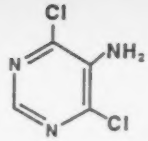
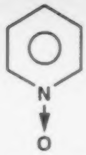
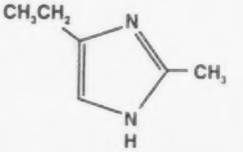


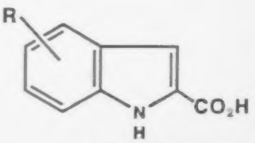
5-Amino-4,6-Dichloropyrimidine



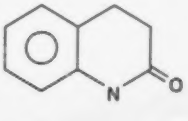
Pyridine N-Oxide



2-Methyl-4-Ethyl-Imidazole



Indole-2-Carboxylic Acids



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CHEMICAL & ENGINEERING NEWS

C&EN

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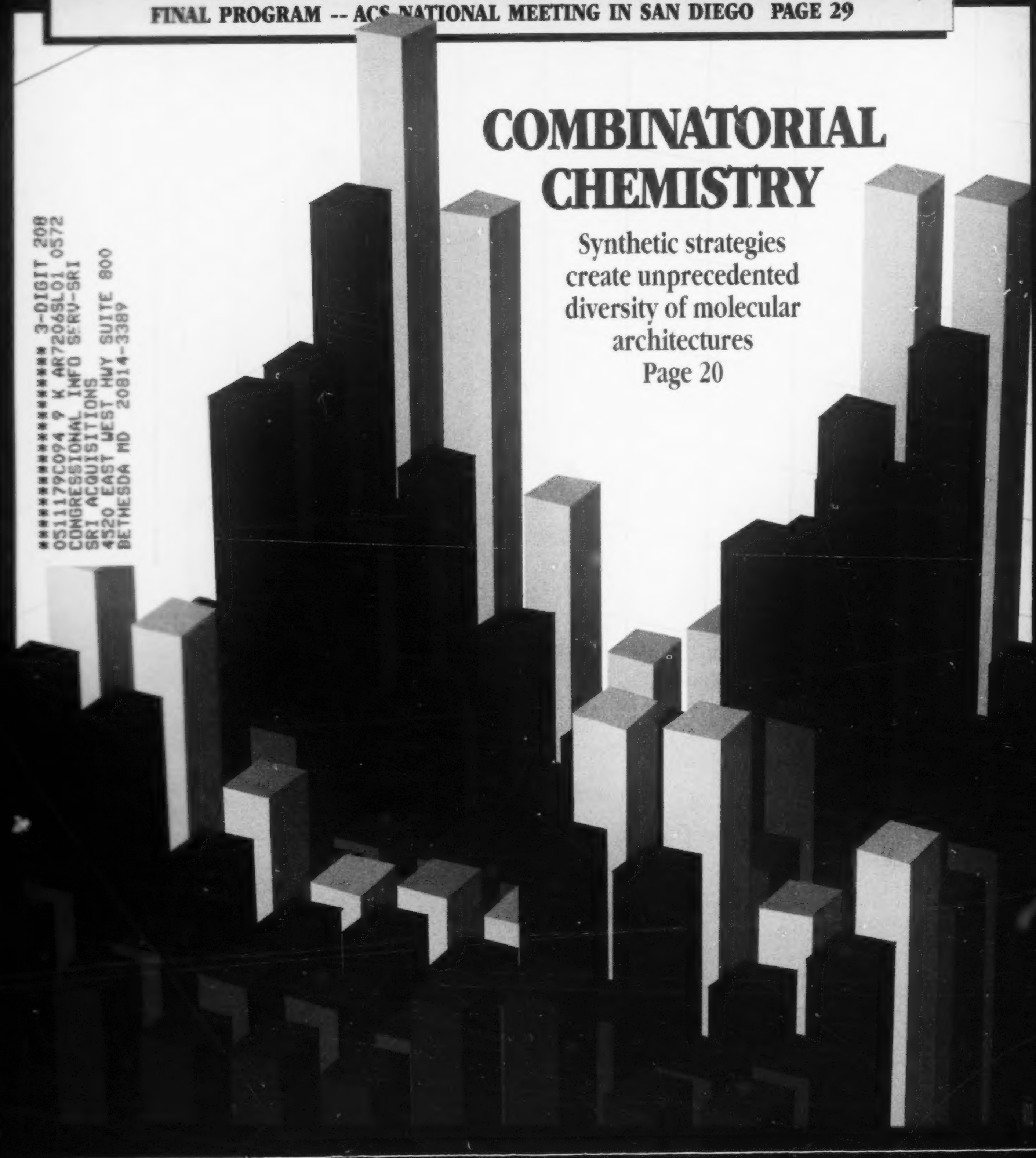

COMBINATORIAL CHEMISTRY

Synthetic strategies create unprecedented diversity of molecular architectures
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CHEMICAL & ENGINEERING NEWS
C&EN
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NEWS OF THE WEEK

- EPA unveils tough proposals for reauthorizing and revamping the Clean Water Act that call for development of a strategy to restrict or ban use of chlorine compounds; chemical industry reacts with outrage. **Page 4**
- Modest electric fields can alter the structure of lipid monolayers that are models of biological membranes, suggesting a mechanism by which electromagnetic fields could affect biological systems. **Page 5**
- Top U.S. researchers meet to help Clinton Administration write a national science policy. **Page 5**
- Chemists in Tennessee synthesize single, highly symmetrical $C_{60}F_{48}$ fullerene isomer by direct fluorination of C_{60}. **Page 6**
- Uncertainty over the Administration's health care reform plan is hurting the biotechnology industry by undermining investor confidence, says an industry survey. **Page 7**
- Administration sends Congress proposal for Superfund renewal and revision; bill called a good first step by industry and environmental groups. **Page 7**

COVER: Detail from a graph of proteolysis data on substrates synthesized combinatorially on a silicon chip using technology developed by Affymax, Palo Alto, Calif.

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BUSINESS

Growing worldwide market for ethyleneamines will be served by fewer, but stronger, companies—led by Union Carbide, Dow Chemical, and units of Akzo and Nobel. **Page 11**

A life cycle study of detergent phosphates, conducted in the U.K., considers the cradle-to-grave environmental effects of phosphates and their replacements. **Page 13**

Business insights: The rate of inflation dipped below 3% in December—raising hopes, housing starts, and car sales. **Page 14**

GOVERNMENT

NSF advises chemists who want to receive federal funding to tie their research to national priorities and to direct more effort to strategic research areas. **Page 16**

Companies and organizations convicted of civil environmental crimes could pay increased fines if newly drafted penalty guidelines are approved by Congress. **Page 18**

SCIENCE/TECHNOLOGY

New strategy for designing organic molecules with nonlinear optical properties produces compounds that are unsurpassed at doubling the frequency of laser light passing through them. **Page 26**

FINAL PROGRAM

ACS national meeting in San Diego will offer attendees more than 5,700 paper presentations in 627 technical sessions, Sci-Mix, 43 ACS national award presentations, and a large exposition. **Page 29**

COVER STORY

Medicinal chemistry gets a boost as methods of combinatorial chemistry provide new ways of generating vast arrays of molecules that can be surveyed for biological activity. Page 20

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LETTERS

Chemists, chemical engineers

I always skim the names in the Letters to the Editor section for the authors and topics of these select missives. Imagine my surprise as a chemical engineer to see that my old friend Ted Logan, a surpassing chemist, was writing about chemists and chemical engineers (C&EN, Jan. 10, page 3). Imagine my pleasure when, having read his letter, it was clear that we had similar views and that he had also either forgiven or forgotten my youthful jibes at chemists when we worked together at Procter & Gamble in the 1960s.

There is only one point that I'd like to add to his thoughts. Chemical engineering, like all engineering, is an art—not a science. It is the art of the practical within the science of chemistry (and even biology and physics these days). Chemical engineers are well-trained artisans when they get their B.S. degrees and therefore are immediately useful to industry. B.S. chemists, on the other hand, are novice scientists and like most novices, are only prepared to learn more about their chosen field or other sciences. The narrowing differences in starting salaries that Logan reports for chemical engineers who remain in school to get M.S. and Ph.D. degrees are a measure of those engineers becoming engineering scientists and therefore more like Ph.D. chemists in outlook and in immediate value to industry.

If B.S. chemistry educations are changed to make chemists into artisans of immediate value to industry, we must face the inevitable fact that those who go on to get advanced chemistry degrees will no longer be novice scientists. That may be either good or bad, but it will certainly be true. It will change academic chemical research. The question is, can we afford the change just so chemists can move up the starting-salary table? I don't know the answer to that question, but it ought to be considered before we change the game plan.

Robert L. Morris
President
Managing Technology Inc.
Williamsburg, Va.

T. J. Logan perceives that the B.S. degree in chemical engineering is financially more valuable to new graduates than is the B.S. degree in chemistry. I agree. He suggests that we raise the market value of the chemistry degree by, in effect, making it a chemical engineering degree. I agree, but only to a point.

I suggest that rather than creating B.S. chemists in the mold of chemical engineers, we simply eliminate curricula leading to the B.S. degree in chemistry. All B.S. degrees in chemical science and technology would be in chemical engineering. They are more valuable to industry and of at least equal value to those going on for graduate work in chemistry. Of course, if all chemical B.S. degree recipients were engineers, their increased numbers would cause the employment market to devalue them too. We can deal with that if we ever come to it.

Donald J. Loundy
Carlsbad, Calif.

Safety regulations

Daniel J. Shanefield "hope[s] that [his] suspicion is wrong" in his letter concerning safety initiatives (C&EN, Jan. 10, page 2). I write to confirm his suspicion and correct his errors.

In the first place, to my personal knowledge, the private records of the chemical industry clearly show that the political movements that resulted in the variety of Occupational Safety & Health Administration (OSHA), Environmental Protection Agency, and other regulations we now have today also persuaded the Chemical Manufacturers Association (CMA) to generate its code of Responsible Care. That is, after many of the federal regulations were promulgated, the chemical industry then generated its own voluntary safety and environmental standards as a way to persuade Congress that additional laws and regulations would not be necessary to im-

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Smaller Group of Stronger Firms Vie For Growing Ethyleneamines Market

■ ***Union Carbide, Dow, and ethyleneamines units of Akzo and Nobel appear to be best positioned to meet increasing demand***

Susan J. Ainsworth, C&EN Houston

Unlike most chemical businesses, which have remained stagnant in the midst of recession, the ethyleneamines business has been reshaped by a number of major changes among producers over the past 12 months. These intermediate chemicals are used in a wide range of applications, including the manufacture of lubricating oil and fuel additives, chelants, polyamides, wet-strength resins, surfactants, fabric softeners, and bleach activators.

Just last month, Dow Chemical, the world's second largest ethyleneamines producer, started up its new 60 million-lb-per-year plant in Freeport, Tex. The plant, which will begin supplying outside customers within the next few weeks, boosts the company's total global capacity to 220 million lb per year. Only a year earlier, Union Carbide, the world's largest producer of ethyleneamines, expanded its capacity by 50 million lb per year at its Taft, La., plant, bringing annual capacity at the company's sole ethyleneamines production site to 230 million lb.

In a move that surprised the ethyleneamines market, in July 1993, Texaco Chemical announced its exit from the ethyleneamines business at year-end 1993, shutting down its unit at Conroe, Tex., and ending a toll production arrangement it had with Air Products & Chemicals.

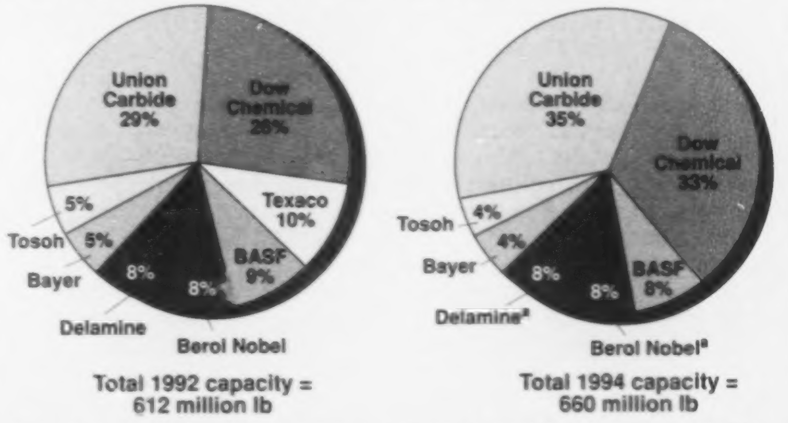
In November, Akzo N.V. and Nobel Industrier A.B. announced their intention to merge; that action is expected to be completed by the end of this month. This clears the way for the linkup between two European ethyleneamines players—Berol Nobel and Delamine, a joint venture formed in 1976 between Akzo Chemicals in the Netherlands and Tosoh Corp. in Japan. An Akzo spokesman says it's too early to tell if, following the merger, Berol Nobel and Delamine will cooperate simply as sister companies or will eventually merge to form one larger ethyleneamines entity.

As a result of these events, the market has become more consolidated, leaving fewer, but generally stronger players who are eager to capture additional market share. To be sure, "The ethyleneamines business has become an increasingly global business with fewer global players," Bert Kroese, general manager of Delamine, tells C&EN from the company's headquarters in Amersfoort, the Netherlands. Together, three producers—Union Carbide, Dow, and the potential partnership between Delamine and Berol Nobel—will control more than 70% of the global sales, he estimates. Ethyleneamines are priced such that transport all over the world is generally not a problem from a cost point of view, and "all three are marketing their products on all continents," adds Kroese.

Although the various changes in the market are adding up to a growing consolidation, it wasn't planned that way, according to Christer A. Andersson, president and chief executive officer of Berol Nobel, based in Stenungsund, Sweden. The potential joining of Berol Nobel and Delamine is merely a consequence of the Akzo and Nobel merger initiated for other reasons. And "the Texaco Chemical exit took place for profitability reasons," he adds. Indeed, Texaco Chemical president Ralph S. Cunningham says the "decision underscores the company's focus on profitable intermediate and specialty chemicals."

Certainly, the ethyleneamines market has not yet reached the stage of its life cycle where rationalization of capacity and reduction of the number of producers have been necessitated by weak growth. On the contrary, "despite the global recession's impact on the chemical industry, the ethyleneamines business is experiencing healthy growth," according to Robert S. Snyder, marketing manager for ethyleneamines at Dow in Midland, Mich. "The traditional ethyleneamine end-use applications have

Fewer producers share global ethyleneamines capacity



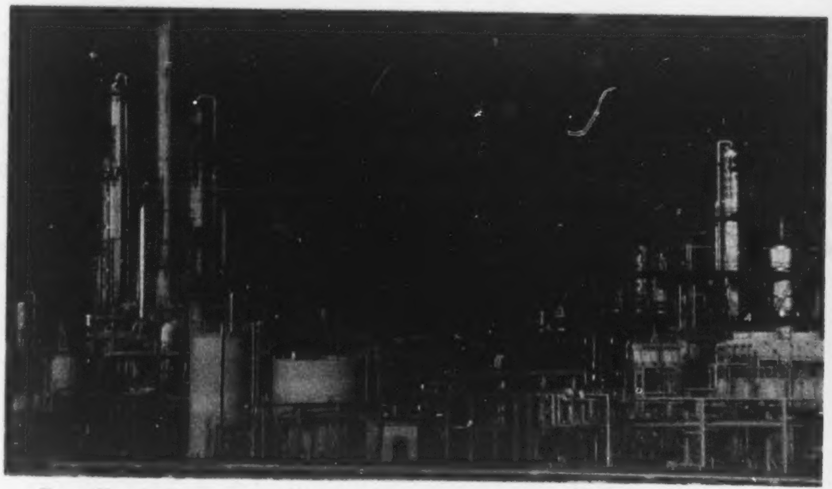
Note: Texaco exited market effective Dec. 31, 1993. a Delamine and Berol Nobel are expected to become sister companies this month. **Source:** Dow Chemical weathered recessionary conditions. Dow projects global demand to grow at an annual rate of 4 to 5% through 1995."

Most notably, future ethyleneamines growth will be fueled by more demanding environmental requirements for automotive lubrication oils and fuel additives under the Clean Air Act, says Snyder. In this end use, ethyleneamines such as diethylenetriamine (DETA) and polyethylene polyamine act as anticorrosives, performance enhancers, ashless dispersants, and detergent additives. In addition, demand for ethyleneamines, such as DETA, that go into wet-strength resins, will get a boost from the increased use of recycled paper in liner board, toweling, tissue, and sanitary products, he adds.

Snyder also expects to see above-average growth in demand for ethylenediamine (EDA), which is used in the bleach activator tetraacetylenediamine. EDA is well-suited for European laundry conditions where wash temperatures are warmer than in the U.S. Eric C. Rogers, product marketing manager for ethyleneamines at Union Carbide, adds that demand for ethylenediamine tetraacetic acid and diethylenetriamine pentaacetic acid, long used as chelating agents, is increasing in the paper industry.

Future market demand growth coupled with Texaco Chemical's exit from the market give producers of ethyleneamines that much more opportunity to expand their market share. Producers also hope the loss of a competitor will allow profit margins to strengthen. Prices for higher homologs have been under pressure since 1990, when Texaco Chemical expanded production, becoming a full-range supplier of ethyleneamines, observes Snyder. "Presumably, Texaco Chemical's exit removes some of that pressure and should help margins," he says.

Kroese agrees. Texaco Chemical took some business "from all producers in the late 1980s, so [its] exit will represent an opportunity for Delamine-Berol Nobel to recuperate from this loss and further improve its market position."



Dow Chemical's new 60 million-lb-per-year ethyleneamines plant in Freeport, Tex.

As Delamine and Berol Nobel become sister companies, they could form "a more powerful and competitive single entity, which will represent more than 20% of the market," according to Andersson. Although both companies have been operating on a global basis, Europe has been by far the most important market. As "a stronger competitor, we will look for larger stakes everywhere," including the U.S. market, says Andersson.

Supplying North American ethyleneamines customers isn't a problem for the two producers despite the fact that Delamine's plant is in Delfzijl, the Netherlands, and Berol's is in Stenungsund. In North America, Delamine has been selling ethyleneamines for more than 10 years through joint-venture parent Tosoh's Atlanta office, Kroese points out. Last year, Tosoh set up a pair of bulk storage tanks at Fairburn, Ga., and has been able to supply customers with Delamine-produced material even on short notice. In addition, Berol Nobel has been distributing ethyleneamines in North America since 1982 from terminals in Bayonne, N.J., says Andersson.

Pulling together the combined market share of Delamine and Berol Nobel gives the newly merged Akzo-Nobel company a "reasonable foothold" in North America, he says. "The U.S. market is growing, which means that the new joined company intends to grow as well."

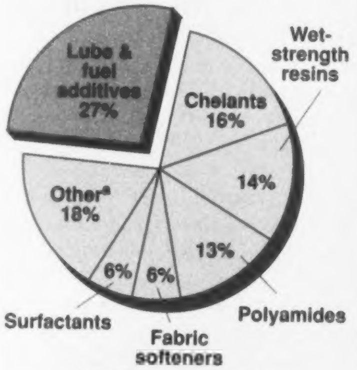
Through their parent companies' merger, Berol and Delamine could each gain access to another of the two commercial production routes to ethyleneamines, allowing them to favor the process that is most economical at a given time. Delamine's Delfzijl plant produces the full range of ethyleneamines (lower amines such as EDA as well as higher amines such as triethylenetetramine) using a process based on ethylene dichloride (EDC). Berol Nobel's plant employs an ethylene-oxide-based route that generates only lower amines.

Union Carbide is the only other world producer that has access to both routes to ethyleneamines. At Taft, units for both processors were upgraded in the expansion. Indeed, that expansion has been a "major step in our effort to strategically strengthen our ethyleneamines business," says Rogers.

The expansion has certainly helped Union Carbide "take advantage of the demise of Texaco Chemical's position in the market and pick up some of its business," adds Rogers. For its part, Union Carbide recently expanded its ethyleneamines product line to include anhydrous piperazine, a product that had been part of Texaco Chemical's ethyleneamines product portfolio.

Similarly, Dow Chemical's new Freeport plant is expected to give the compa-

Lube and fuel additives lead ethyleneamines use



1993 North American consumption = 200 million lb^b

a Includes silicone derivatives, corrosion inhibitors, and phosphate mining chemicals. b Union Carbide estimate. **Source:** Dow Chemical ny an edge in the market, allowing it more room for sales growth. Another advantage for Dow is its ability to supply "a full product line from multiple locations, which is important to our global customers," says Snyder. Dow has two plants in Freeport, with a combined capacity of 160 million lb per year, and a 60 million-lb-per-year plant at Terneuzen, the Netherlands, making it the only producer with world-scale manufacturing facilities in both the U.S. and Europe. "This flexibility enables us to accommodate the various homolog mixes demanded by our customers," he says.

Although Dow is "definitely trying to get our share of the market," Snyder says, "we have not rolled out any new programs or made any major marketing changes in response to the recent events in the market for ethyleneamines. Because we've been in the business for so long, we are in most of the established accounts and applications already and we have been doing business with many of Texaco Chemical's former customers all along." ☐

Detergent phosphates revisited in study

According to a new study, phosphate-free detergents are no better for the environment than those containing phosphates. Alternatives such as zeolites can do just as much harm to the environment. Furthermore, there may even be economic benefits to using phosphates, recovering them from wastewater, and recycling them. Those are among the major conclusions of "The Phosphates Report," just published by the Landbank Consultancy of London.

The study was funded jointly by the European Center for Phosphate Studies and Albright & Wilson, the British chemicals subsidiary of Tenneco, which is a producer of phosphates for detergents. However, the authors insist that they have been independent and objective. One of the authors, Bryn Jones, was a director of the environmental activist group Greenpeace in the U.K., and the other, Bob Wilson, formerly was a senior lecturer in statistics at what is now the University of the West of England, Bristol.

Phosphate builders for detergents have been an environmental concern for the past 20 years for their contribution to speeding up eutrophication—the excessive growth of algae and subsequent lowering of oxygen levels in rivers, lakes, and other waterways. As a result, governments in various regions in Europe and the U.S. have banned phosphates from detergents, requiring formulations with alternative performance-enhancing additives, although phosphates from other sources have not been controlled.

According to this study, however, "When assessed on a full cradle-to-grave basis, from the extraction of raw materials through processing, manufacture, use, and ultimate disposal, both zeolite and phosphate had an almost identical impact on the environment. Phosphates, however, have one enormous advantage over zeolites, and over all other detergent builders, in that they can be easily and cheaply recovered from wastewaters for recycling."

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C&EN

FEBRUARY 14, 1994

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- Funding for R&D is boosted 4% in Clinton's proposed federal budget for fiscal 1995, in contrast to cuts in many other programs imposed by deficit reduction caps. **Page 4**
- U.S. chemical industry is looking at opportunities in Vietnam following the White House's decision to end the long-running U.S. trade embargo against that country. **Page 5**
- Scientific community is urged by National Academy of Sciences, National Academy of Engineering, and Institute of Medicine to face up to scientific misconduct and work actively to prevent it. **Page 6**
- Two research groups have independently developed completely different total synthesis routes for the anticancer drug taxol. **Page 6**
- BASF has concluded a deal to buy ICI's polypropylene operations, joining other efforts to consolidate the fragmented polyolefins industry in Europe. **Page 6**
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LETTERS

Stereochemistry vocabulary

I am rarely in favor of inventing new terms to replace perfectly good old ones. But at the risk of violating this personal policy, I would like to offer some suggestions about several stereochemical terms that are sometimes misused, and get the reaction of interested C&EN readers.

The term *stereogenic center* is currently used to describe what was once called an asymmetric (or chiral) atom. I would like to propose a more meaningful definition of this and several related new terms. If we accept *stereogenic* as meaning "giving rise to stereoisomers," then a *stereogenic atom* can be defined as an atom where interchange of two of its substituents gives rise to a different *stereoisomer* of the original molecule. (This is essentially the definition given by G. E. McCasland, as cited by K. Mislow and J. Siegel [*J. Am. Chem. Soc.*, **106**, 3319 (1984)]).

Because stereoisomers are further subdivided into enantiomers and diastereomers, I suggest defining two types of stereogenic atoms—enantiogenic and diastereogenic. An *enantiogenic atom* is an atom where interchange of two of its substituents gives rise to the enantiomer of the original molecule, whereas a *diastereogenic atom* is an atom where interchange of two of its substituents gives rise to a different diastereomer of the original molecule. Clearly, the usual situation of a tetrahedral atom with four different substituents is an example of an enantiogenic atom. In molecules with multiple stereogenic atoms, for example, 2,3-dibromobutane, the bromine-bearing carbons would be diastereogenic atoms (not enantiogenic) because interchange of any pair of substituents on either atom would lead to a different diastereomer. Similarly, atoms that used to be described as "pseudoasymmetric" would now be more accurately described as diastereogenic.

A stereogenic *center* (stereocenter) can next be defined as an atom or *linkage (grouping) of atoms* where interchange of two substituents at the atom or at one end of the linkage gives rise to a different stereoisomer of the original molecule. A stereogenic center can be either an *enantiogenic center* (enantiocenter, an atom or linkage of atoms where interchange of two substituents at one end of the linkage gives rise to the enantiomer of the original molecule) or a *diastereogenic center* (diastereocenter, an atom or linkage of atoms where interchange of two substituents at one end of the linkage gives rise to a different diastereomer of the original molecule). Thus, the term enantiocenter would include a suitably substituted allene linkage, spirocyclic ring, nonrotating biphenyl system, or similar structural unit, as well as an enantiogenic atom. A suitably substituted carbon-carbon double bond (that is, where geometric isomers are possible) would be an example of a diastereocenter.

With these definitions in place, the maximum number of stereoisomers possible for a given structure equals the familiar 2^n, where n is the total number of stereocenters. (The actual number of stereoisomers would be less when the molecule is symmetrical.) Thus, 3-penten-2-ol has one enantiocenter (the OH-bearing carbon) and one diastereocenter (the double bond) and can exist in four stereoisomeric forms (two pairs of enantiomers): (*cis-R*), (*cis-S*), (*trans-R*), and (*trans-S*). On the other hand, 2,4-hexadiene has two diastereocenters (the double bonds), so it exists as four different diastereomers: (*cis, cis*), (*cis, trans*), (*trans, cis*), and (*trans, trans*). Molecules with two diastereogenic atoms (for example, 2-bromo-3-chlorobutane) would give rise to four stereoisomers (two pairs of enantiomers): (2*R*,3*S*), (2*S*,3*R*), (2*S*,3*S*), and (2*R*,3*R*). Note that the *R/S* configurational nomenclature system is applicable to enantiocenters as well as many diastereogenic atoms.

There has also been some confusion in the way the term *chiral* is used. The purest definition is "to possess handedness," that is, to be dissymmetric. We often define it further as "having an enantiomer (a nonsuperimposable mirror image)," or as "capable of existing as enantiomers." Is it then correct to say that 2-bromobutane is chiral? Or is it only the individual enantiomers of 2-bromobutane that are chiral? Certainly when we encounter "chiral reagents" we infer that they are enantiomerically pure or at least enantio-enriched. If "chiral" applies only to the enantiomers of 2-bromobutane, then what term describes the fact that 2-bromobutane is capable of existing in enantiomeric forms? I suggest that 2-bromobutane could be described as enantiogenic, that is, giving rise to enantiomers, and also as possessing one enantiogenic center. We can reserve the term *chiral* for specific structures that have a nonsuperimposable mirror image.

Roger S. Macomber
Department of Chemistry
University of Cincinnati

Correction

- Jan. 31, page 30: The headline of the chart and its horizontal axis should refer to weeks, not months.

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European Chemical Industry Struggles To Remain Competitive

■ ***Governmental and social strictures are cutting into ability of European producers to compete globally***

Patricia L. Layman, C&EN London

Europe has discovered competitiveness—the need to be able to keep up with industries from around the world. Competitiveness has become the consuming topic of national governments and the European Union (EU), as the European Community is now known, in response to what is becoming clear: As the century moves to its close, European industries cannot compete effectively.

One of Europe's most successful industries—chemicals—is helping lead the fight to improve conditions promoting competitiveness. Its lobbying efforts are given weight by the fact that the industry is a solid contributor to the EU's balance of trade, still maintaining a trade surplus, while many other industries have slipped into a trade deficit.

However, the chemical industry is hampered by high unit labor costs, which represent 23% of output value, compared with 13% in the U.S. and 9% in Japan, as well as energy costs significantly higher than those in the U.S. and Middle Eastern countries. Spending on environmental protection now takes roughly 15% of capital spending in the German chemical industry, and nearly as much in the U.K., compared with about 10% in the U.S. and less than 5% in Japan. One of the few "lower" measures is hardly comforting—R&D spending by the European chemical industry is probably about 5% of sales, compared with roughly 6% of sales in the U.S. and nearly 6.5% in Japan.

Margetts: market position, technology are important for company survival

With specific areas of concern that leaders in the chemical and other industries have targeted, and with other, different areas acknowledged by many politicians, industry leaders and politicians are slowly moving toward a center ground. Finding the will and the way to accomplish effective goals for European competitiveness will be a difficult process, but efforts have begun.

Late last year, a report issued by UNICE, the Union of Industrial & Employers' Confederations of Europe, looked at "Making Europe More Competitive: Towards World-Class Performance." At about the same time, the European Round Table, a group of senior industrialists from throughout Europe, issued "Beating the Crisis." This report is an action plan designed, in part, to rebuild competitiveness for European industries.

Both were timed to coincide with the December release by the European Commission (the administrative arm of the EU) of the white paper by commission president Jacques Delors on "Growth, Competitiveness, and Employment." The paper calls for specific growth targets for the economy and for the need for stability in economic and regulatory policies.

Two months before that, the European Chemical Industry Council (CEFIC) had presented to Delors and other commissioners its consultative paper "Focus on Competitiveness" as its contribution to the white paper. The white paper itself is considered by the European Commission as "an analysis of the situation and a starting point for action."

As CEFIC noted at the time, "As a major supplier to other industry sectors, and therefore a key contributor to overall economic growth, the European chemical industry proposes a series of measures to restore competitiveness and reverse the decline in Europe's position on the world scene."

Among other points, CEFIC emphasized the need for flexibility in labor markets, affected in part by a reduction in government-required compensation levels of all sorts. However, CEFIC noted, "It would be inappropriate to contemplate the compensation of a reduction of the labor costs by new taxes, such as the proposed carbon dioxide-energy tax, as this would not improve the competitiveness of industry. Energy prices in Europe are already 40% higher than in the U.S.A."

Competitiveness was one of the key themes of the U.K. Chemical Industries Association's (CIA) mid-January annual business outlook conference, cosponsored by CEFIC. For Clive Thompson, vice president of Arco Chemical Europe, Maidenhead, U.K., the conference provided the setting for considering how to mesh competitiveness with the laudable concept of sustainable development. As he pointed out, sustainable development "presupposes that the basic economy is healthy, and that society understands the trade-offs and sacrifices necessary to take on the sustainability commitment."

It is clear, he added, that the European economy is suffering from structural problems, and that "within the economy there are few bright signs of competitiveness in the different sectors of the chemical industry. There are those who point to the fact that we are at the bottom of both industry and economic cycles and, while this is true, we should not expect a normal economic recovery to solve our problems."

In the U.S., between 1974–91, some 70% of the working population was employed. In the EU, the proportion was 59%, he observed. In the U.S. during that period almost 30 million new jobs were created; in the EU, the number of new jobs created reached only 3.1 million.

"In our endeavors to protect employment, we have failed to create new jobs and through the high total cost of employment including salaries, short working weeks, and social costs, we are pricing ourselves out of work," Thompson said. Moreover, although the energy-intensive industries of Western Europe have long complained about high energy pricing, EU governments have traditionally used energy as a source of taxation. The result is that European industries face energy pricing that is not competitive with the U.S. and Middle Eastern countries and, although the region is the most energy efficient internationally, it faces another possible energy tax on carbon dioxide generation.

"Future legislation," Thompson concluded, "must only be considered where there are clear and quantifiable objectives. If applied, economic instruments should be well targeted and should be fiscally neutral. Above all, they should not distort competition."

For Rob Margetts, a director of ICI and a CEFIC board member, there is also a "micro" dimension to the competitiveness problem—what each company can do for itself. As he contended at the CIA conference, only those chemical companies that can achieve and sustain international competitiveness will survive the increasingly tough next 10 years.

Power costs in Europe exceed costs in U.S.

Index (U.S. = 100)	Gas	Electricity
U.S.	100	100
Germany	156	163
Italy	156	122
U.K.	147	114
France	145	132
Netherlands	123	106

Source: Dow Chemical, Arco Chemical Europe

The key to corporate survival, he suggested, lies in a company's organizational "architecture." "The way a firm arranges all the pieces or building blocks within its organization is the key to international competitiveness," Margetts said. And among the most important building blocks for a chemical company are market position and technology.

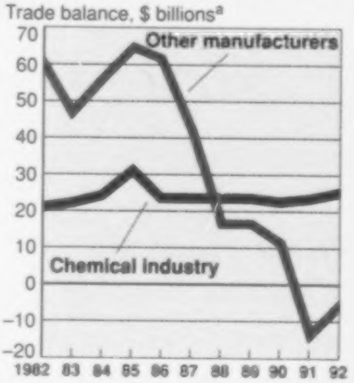
Market position takes into account the firm's position in the lineup of international companies, not only globally and within the different regions of the world, but also in the different sectors of each product market. Not surprisingly, he observed, "with size and coverage, a firm can have important unit-cost advantages through economies of scale in a wide number of activities, including purchasing, manufacturing, distribution, and marketing."

Market position can offer other potential competitive advantages, including spreading the costs of R&D across a number of markets. This improves the company's new product and process development capability and enables the firm to form partnerships with major customers.

Technology, he argued, is vital in supporting market position and cost competitiveness. He warned against various myths about the role of technology in achieving competitive advantage: "The most dangerous of these is the widely held belief that technological superiority is itself sufficient." To make technology work effectively, individual companies must turn it into tangible results in the market. Moreover, in the chemical industry, state-of-the-art technology is essential in term of both products and processes.

The numerous points drawn out in papers and discussions at CIA's business outlook conference found reinforcement a week later at the annual start-of-the-year press conference of the Association of the German Chemical Industry (VCI), in Frankfurt. As VCI president Gert Becker, chairman of Degussa A.G., noted, "Economic recovery alone will not solve our current problems [in Germany]. The global playing field has changed dramatically for our industry. Today, many products can no longer be produced in a competitive manner in Germany as a location. In many countries, the costs of feedstocks, labor, energy, and environmental protection, as well as taxes and social security contributions, are far lower than in Germany, and the quality of goods they produce is satisfactory."

Chemicals play strong role in EU trade balance



a Constant dollars, year-end 1993.
Source: European Chemical Industry Council

Measures to reduce costs alone are not a suitable way of safeguarding the future, he said. Rather, the chemical industry in Germany can only be successful in the long term if it succeeds in putting innovative products on the market. And "innovations only help when they can be rapidly implemented," said Becker.

"We believe it is a major step forward that all the main parties have recognized that deregulation and the dismantling of bureaucratic obstacles are among the most important tasks in economic and research policies," Becker observed. "The German chemical industry is of the opinion that the promotion of fundamental research at universities and institutes, as well as the promotion of applied research and development technologies of the future, such as biotechnology and genetic engineering, are the right approaches." However, he continued, "companies must be free to make their decisions about research and development and to orient these decisions toward the needs of the market."

The return to a more competitive Germany, Becker suggested, will not be easy. "There are many different areas in which politicians are called on to safeguard and improve the performance of our national economy and the basis for our standard of living." These include, for example, dismantling some of the taxes that make it disadvantageous to invest in Germany compared with other countries; consolidating much of Germany's social legislation; and reducing the country's national debt. "We very much welcome the fact that politicians have begun to rethink their attitudes and that first steps in the right direction are being taken," he added.

That message has gotten through to the opposition political party, the Social Democrats, and to IG Chemie, the chemical workers' union, which has about 800,000 members. The two groups have published a joint plan that attempts to balance environmental demands with the preservation of jobs.

Some of the key recommendations of the plan are the simplification of environmental legislation, acceleration of planning procedures to speed introduction of "green" products, and a clear timetable for legislation on chemical wastes.

Much of the action by the governments of the various European countries, however, will be influenced by the policy now being devised by the European Commission, which was addressed in the white paper by Delors. The white paper was written to encourage the 12 member countries to increase capital spending in a drive to create 15 million jobs by the year 2000, thereby cutting current unemployment rates in half.

The paper contains three central messages: First, that the EU needs to get back on what the commission calls the "growth path": annual growth in the EU economy of at least 3% up to the year 2000, although "there will obviously be some transitional problems and a need to build up to a higher growth rate again." Some of the main criteria for such growth are a higher rate of investment—23 to 24% of gross national product, up from the current level of about 19%; an increase in savings; stability of macroeconomic policies; and attention to rebuilding confidence.

Second, the commission sees the need for more jobs. "While still keeping our basic social security protection, the EU can use the economic growth to create more jobs, particularly by removing obstructions to mobility of labor and part-time work."

And third, the white paper cites the need for medium- and longer term measures to improve competitiveness, in part by making the best use of the single market; conducting R&D; carrying out education and training; encouraging small- and medium-sized businesses; adapting to new technologies; and investing in the trans-European networks [telecommunications, transport, energy, and the like] both within the EU and in Central and Eastern Europe as well.

The commission says that what the white paper actually proposes are measures "to create an environment more favorable to enterprise within the internal market, including an integrated program for small- and medium-sized enterprises." A strategic program for the internal market is being written separately, officials add, and will include measures such as reorienting public intervention toward growth markets; revising the mechanisms and criteria of public intervention to avoid conflict between industrial competitiveness and job creation; and promoting "immaterial" investment for research, training, and know-how.

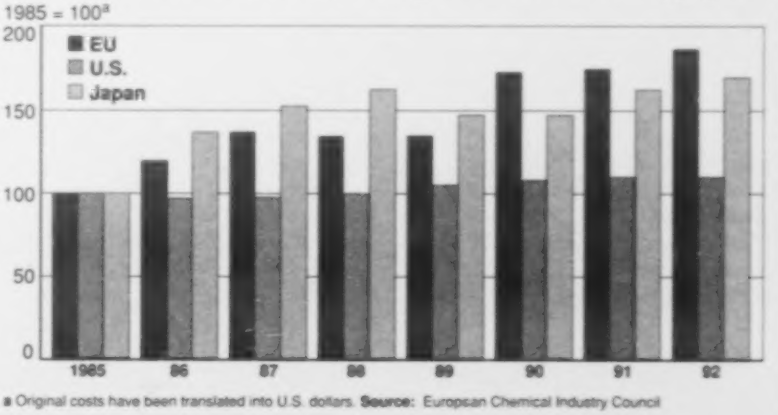
Among the areas the commission specifically mentioned were biotechnology, "where the early use of research resources will make for greater synergy between chemical companies and the big potential users in the health and agri-foodstuffs sector," and what it called ecotechnologies—"radical innovations targeting the causes of pollution and aiming at environmental efficiency through the production cycle. Ecotechnologies will soon provide a major competitive advantage."

The commission's comments on biotechnology, for one, struck a responsive chord among chemical companies in that field. Earlier, in October, the U.K. House of Lords' Select Committee on Science & Technology had issued a report on the regulation of the British biotechnology industry and global competitiveness. British industry greeted the report favorably.

Typical of the response was the "wholehearted" welcome of the report by Peter Doyle, R&D director of life sciences company Zeneca. "The Lords have recognized not only the proven advantages provided by biotechnology, but also the extent of future benefits which the technology offers to mankind," he said. Moreover, implementing the findings in the report "will enhance the abilities of companies involved in biotechnology to be internationally competitive, by speeding up the approval of new products and reducing the cost of their development.

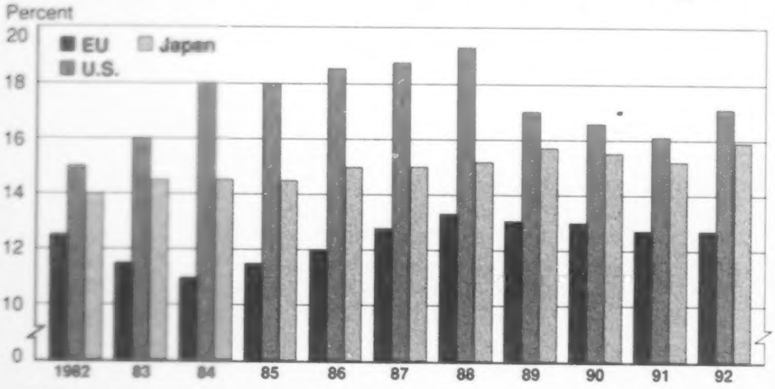
"The Lords recognize that a biotechnology product or process should be evaluated on its individual merits and not on the basis of the techniques by which it was developed or made. Zeneca agrees with the Lords that elements of the U.S. regulatory system, which undertakes evaluation on this basis, and which is also easy to understand, efficient, and cost-effective in its use of

Chemical unit labor costs have grown faster in EU, Japan



[a] Original costs have been translated into U.S. dollars. **Source:** European Chemical Industry Council

European business has lowest rates of return on capital



Note: Data are for all industry. **Source:** Union of Industrial & Employers' Confederations of Europe

the taxpayers' money, are to be applauded," Doyle added.

Comments on developing work such as biotechnology and ecotechnology from various governmental bodies, in particular, are bringing the competitiveness challenge into sharper focus. The efforts seem to be coming down to a drive by countries and companies to concentrate on technology and increasingly sophisticated R&D.

The Organization for Economic Cooperation & Development, for example, is preparing "a comprehensive strategy" to promote sustainable growth and employment for the 1990s, to be completed this year. One of the major topics addressed will be high-technology development. The plan calls for, among other things, the development and diffusion of technological change as the principal source of new skill-intensive jobs; competition, both national and international, spurring development of new technologies; and encouragement of private-sector enterprises, particularly new firms or transformed existing ones, to reap the benefits from new technological opportunites and create viable jobs.

Innovations in high-technology areas of chemistry should be sought, as should better understanding and acceptance of new techniques by both the authorities and the public, CEFIC argued in its consultative paper last October. Industry has the ability and capacity to innovate and to provide the best and least expensive solutions to solve present-day problems, provided, however, that industry is given enough time and freedom to develop these solutions, CEFIC pointed out. And R&D and technological development should be fostered through academia, establishing a scientific infrastructure of global excellence.

Economic problems cannot be solved by the repeated addition of new taxes, added Hugo Lever, CEFIC's director general. Instead, the legislation jungle must be cut away, rather than be allowed to spread. That would improve profitability and help raise European industries' low rates of return on capital.

In CEFIC's analysis, erosion of competitiveness leads to a loss of market share in world exports, which in turn leads inevitably to declining economic growth—and increasing unemployment. The root cause of Europe's economic malaise is thus the erosion of the competitiveness of its manufacturing base. "This does not mean that Europe's economy in general is based on globally uncompetitive foundations, but it does mean that these foundations have been weakened over the years by governmental intervention that has either been inadequate, misdirected, or counterproductive," CEFIC said.

And CEFIC's chemical-industry-oriented analysis, in turn, tied in neatly with the more general recommendations of the European Round Table in its December paper on competitiveness. "What government can do," the paper stated, "is to enable industry to do its job, especially by action leading to the goals of lower costs, fewer regulations, and higher quality.

"Uncertainty is the enemy of investment, and it has been fueled by exchange rate instability, changing political priorities, and unpredictable proposals on trade policy, competition policy, taxation, and energy costs. Governments should demonstrate their commitment to consistent economic policies that will generate confidence in Europe as a good place in which to invest."

Governments also have the task of cutting the level of their own waste, which eats away at the economy. "What is needed to reduce public spending is not public poverty but lean government based on value for money," the Round Table said. Its report concluded that Europe's political leaders need to do three things: commit themselves to a charter for industry, setting out a strategic approach to economic recovery and listing specific policy priorities; set up a European Competitiveness Council representing industry, government, and science, to advise on and monitor the detailed implementation of the charter; and put the charter into full effect through practical policy decisions to rebuild the competitiveness of Europe.

As VCI's Becker acknowledged, "Both political and industrial representatives will need to show courage and determination in the next few years in order to bring our country back onto a successful course." And although he was referring specifically in that statement to the chemical industry in Germany, his point can be extrapolated throughout the European chemical industry: "The chemical industry will do everything in its power to match [politicians'] efforts," Becker said. "We consider the crisis as an opportunity and are prepared to accept the challenge imposed by structural changes."

"The key to Europe's competitiveness is adaptability—by individuals and governments as well as firms," said Carlos Ferrer, president of UNICE, at the launch of that confederation's report. "Firms must be able to respond quickly to changes in the business environment. But they cannot do that if they are weighed down by the rigid legislative constraints and high-cost burdens prevalent throughout the community.

"Europe's lack of competitiveness is evident and the major concern now is that the future could be even bleaker. The pace and scale of change will increase, and threaten to leave Europe even further behind in the global trading competition in years to come, if action is not taken now," he added. ☐

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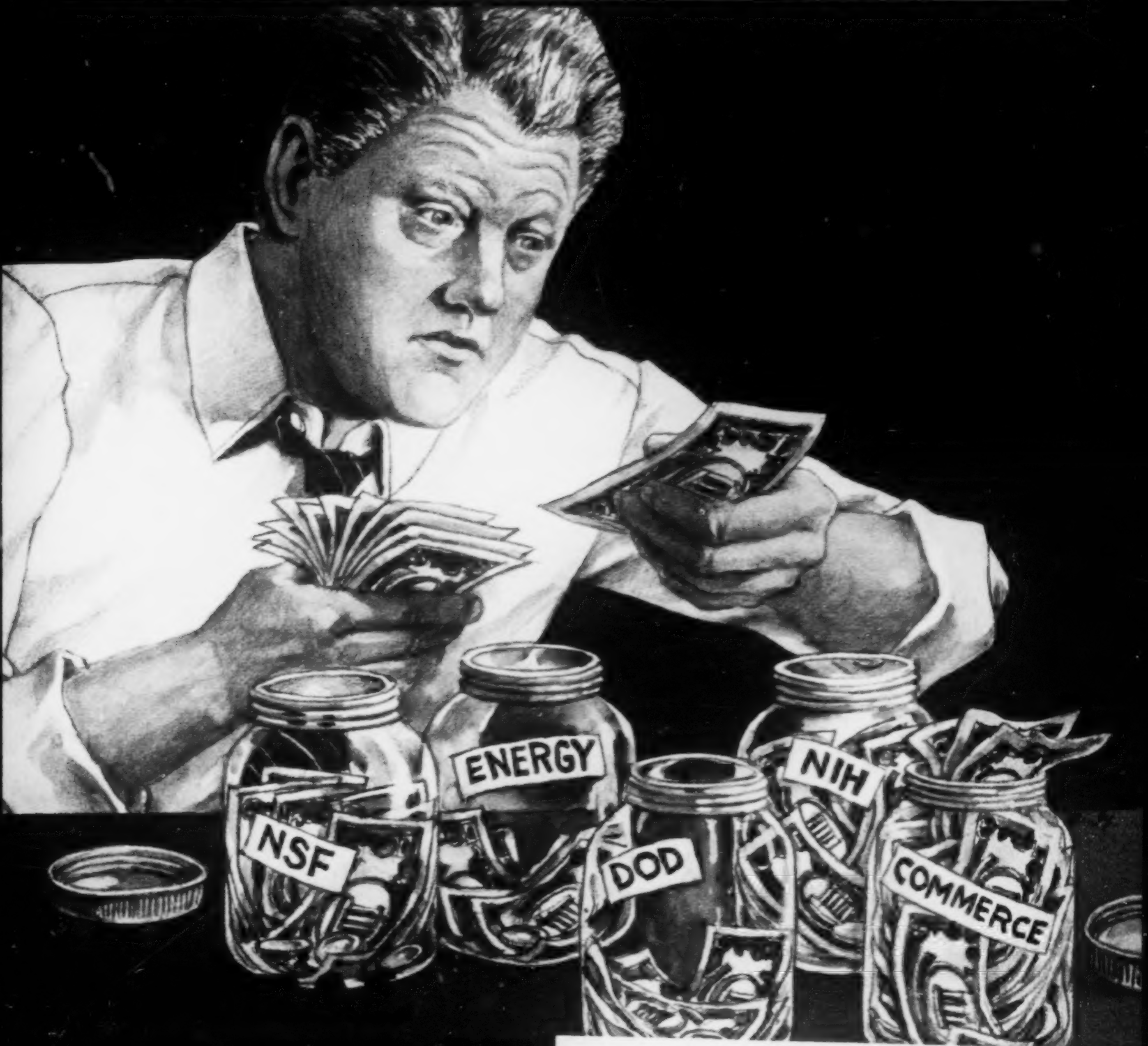
CHEMICAL & ENGINEERING NEWS
C&EN
FEBRUARY 21, 1994

CHEMICAL COMPANIES FINALLY SAW EARNINGS INCREASE IN 1993 PAGE 10



For fiscal 1995, Clinton stresses res
relevant to national needs Page 20

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CHEMICAL & ENGINEERING NEWS

C&EN

FEBRUARY 21, 1994

NEWS OF THE WEEK

- Three former manufacturers of silicone breast implants have pledged more than $4 billion to fund a proposed settlement plan to compensate women who claim their health has been compromised by the implants. **Page 4**
- Persistent toxic substances released to the environment—such as chlorine and chlorinated organics—pose a serious risk and their use must be phased out, says the International Joint Commission, adding fuel to the ongoing debate over acceptable risk. **Page 5**
- NIH decides not to appeal the Patent & Trademark Office's rejection of its application to patent thousands of fragments of human genes. **Page 5**
- Moscow court sends back for review charges against Russian chemist of divulging state secrets, in what may be a prelude to dropping the case. **Page 6**
- A laser-based technique for measuring carbon isotope ratios in gases that is simpler, more specific, and less expensive than the current process may broaden use of carbon-13 tracers as an analytical tool. **Page 6**
- Space shuttle mission that conducted materials processing and biotechnology experiments is hailed as success despite some glitches. **Page 7**

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BUSINESS

Recovery seems to be at hand for the U.S. chemical industry as major chemical companies finish 1993 with an earnings increase for the third straight quarter, ensuring a rise in earnings for all of 1993. **Page 10**

The outlook for Western Europe's petrochemical industry continues to be gloomy, weighed down by a plethora of problems, including overcapacity, high fragmentation, poor profitability, and increasing foreign competition. **Page 15**

More chemical companies and electric utilities are forming partnerships to supply energy services to the chemical firms' plants, providing the companies with the benefits of self-generation without the headaches. **Page 17**

SCIENCE/TECHNOLOGY

Total synthesis of the anticancer drug taxol is achieved by two independent groups using completely different strategies within six weeks of each other; but neither method appears to be of practical use for commercial production of the chemical. **Page 32**

Peroxovanadium complexes have been found to have potent insulinlike activity, suggesting they could be orally active alternatives to injectable insulin. **Page 35**

AWARDS

The ACS Division of Biological Chemistry announces winners of the 1994 Repligen, Lilly, and Pfizer awards. **Page 37**

GOVERNMENT

Clinton's proposed budget for fiscal 1995, submitted to Congress on Feb. 7, calls for a slight increase in federal R&D spending and emphasizes areas selected by the Administration as national needs. Page 20

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LETTERS

Opinions on environmentalism

Bravo to Fred Tausch Jr. for his letter on the hazards of excessive environmentalism (C&EN, Jan. 31, page 5). He makes many valid points that should cause ACS to play a larger role in helping voters to distinguish between environmental science and environmental politics. However, Tausch fails to recognize that many ACS members rely on the environmental industry for their financial support and therefore have little incentive to bring a sense of moderation, balance, and truth to environmental issues. It is unlikely that ACS will respond the way he suggests because of this vocal constituency.

I strongly recommend that all ACS members read Michael Fumento's recent book "Science under Siege" (William Morrow & Co., New York, N.Y., 1993) for a chilling account of how the environmentalists have contrived to make the U.S. a third-rate nation by robbing us of technical advances and by obscuring the true cost to our economy of environmental overregulation.

Melvin H. Gitlitz
Berwyn, Pa.

Remarks in the letter by Fred Tausch Jr. deserve comment. Tausch would have ACS deal "with this [environmental] movement effectively" to return "good jobs at good pay for everyone" to the U.S. Not mentioned is the fact that those jobs depended in part on the acceptability of freely discarding waste materials into the air, water, and land. The implication is clear that ACS should advocate less restrictive waste discharges into the environment. I suggest that the opposite policy is more rational.

Accumulating human waste discards have already poisoned the global environment in visible ways. At present, environmental concentrations of lead and methyl mercury are demonstrated human hazards; DDT and dioxanes are suspect. Freons and carbon dioxide are below human toxicity levels but still are threatening to humans for other reasons. In addition, the same issue of C&EN brought news of a completely new environmental poison—accumulating estrogens.

It may seem surprising at first, but in the absence of humans, wastes generated by other life forms and discarded into the environment do not accumulate. It seems a general principle of nature that wastes may not accumulate in the biotic world. That makes eminent good sense when one remembers that a sufficient accumulation of waste from any life form is poisonous to that life form and to others as well. The millions of species of flora, fauna, and microbiota living in the world interactively consume and transform the wastes of all species to jointly create a benign environment wherein all species escape the threat of extinction as a result of poisoning caused by wastes accumulated in the environment. This is the pivotal center of environmental concerns.

The corollary is that humans must do their part to maintain a benign environment or invite extinction—there is no intermediate choice. Humans, however, do not participate in the myriad intricate interdependent cycles of waste consumption and transformation in the biotic world; humans only generate and discard wastes into the environment. Fortunately, the biotic community has excess waste-transforming capacity that humans can use. Humans are actually parasitic on the remainder of the biotic community for waste transformation service.

Not only are humans dependent upon the biotic world for the food service essential to short-term survival, but also for the waste transformation service that is essential to long-term survival, a fact that we are just beginning to appreciate. The excess waste-transforming capacity in the nonhuman biotic world is a fact-of-life limitation on human activity.

Far from being a hazard to humanity, environmentalism seeks to preserve *Homo sapiens* from early extinction. ACS should endorse this goal rather than oppose it.

Carlyle Herrick
Environmental Consultant
Alplaus, N.Y.

I read with great interest the letter by Fred Tausch Jr. about the hazard of environmentalism. His points regarding the misallocation of public funds and the politics surrounding the environmental movement are right on target. However, I resent his characterization of environmental compliance, regulation, and enforcement jobs as "adversarial, make-work" positions that eliminate "good jobs." Comments like these perpetuate the stereotype that the only "good" chemistry jobs are industrial or laboratory positions.

On the contrary, many chemists and chemical engineers find the environmental compliance field to be an excellent source of rewarding and challenging jobs. My

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Big Fourth-Quarter Earnings Increase Buoyed 1993 Results

William J. Storck,
C&EN Northeast News Bureau

Chemical company fortunes are finally beginning to pick up. After four straight years of decline for the chemical industry, recovery seems at last to be at hand. Between the end of 1988 and the final quarter of 1992, earnings from the 30 chemical companies regularly surveyed by C&EN had fallen a total of 38%. Now, however, they have started back with an estimated 8% rise for all of 1993. Certainly this does not bring them all the way back to what they once were, but it's a start.

When the year began, it did not look like 1993 would be any better than the previous years. After all, earnings in the first quarter were still down from the comparable year-earlier period, extending a long string of declining results. However, in the second and third quarters, business began to pick up and chemical companies finished the year with a strong fourth-quarter performance. Earnings from 28 of the 30 regularly surveyed companies increased 36% in the final period. By press time, Stepan and Lubrizol had not yet reported fourth-quarter earnings, but when they do, their figures likely will make little difference in the overall rate of growth.

The 1993 earnings increase for chemical companies, while good, lagged the average percentage increase for oil companies—10 companies surveyed showed an average increase of 27%. It was also behind the 22% average increase for nine diversified firms that are large producers of chemicals.

The percentage increase for chemical companies did beat that for a group of nine pharmaceutical firms, whose earnings rose an average of just 5%. However, many of these drug companies had unusual charges that could not be separated out.

While chemical companies did increase their earnings in the second and third quarters, it was the fourth quarter that seemed to be the true turning point if the recovery is sustained. The 36% increase in chemical company fourth-quarter earn-

Chemical industry leaders for fourth quarter . . .

Sales				Earnings[a]			Profitability		
Rank 1993		$ Millions	Rank 1992		$ Millions	Rank 1992		Earnings as % of sales	Rank 1992
1	Dow Chemical	$4,505.0	1	W. R. Grace	$85.2	1	Great Lakes Chemical	15.7%	1
2	Monsanto	1,882.0	2	Dow Chemical	82.3	12	International Flavors	13.7	2
3	W. R. Grace	1,192.0	3	Air Products	75.1	2	Nalco Chemical	11.7	5
4	Union Carbide	1,073.0	4	Great Lakes Chemical	69.9	3	Loctite	9.7	3
5	American Cyanamid	985.4	5	Arco Chemical	68.0	5	Air Products	9.1	6
6	Arco Chemical	840.0	7	Hercules	58.3	6	Betz Laboratories	9.0	4
7	Air Products	827.3	6	Morton International	53.7	9	Crompton & Knowles	8.8	7
8	Rohm and Haas	760.0	8	Monsanto	46.0	17	Hercules	8.2	13
9	Hercules	714.7	9	Union Carbide	44.0	15	Arco Chemical	8.1	10
10	Morton International	690.9	12	Nalco Chemical	40.8	7	Imcera	7.9	8

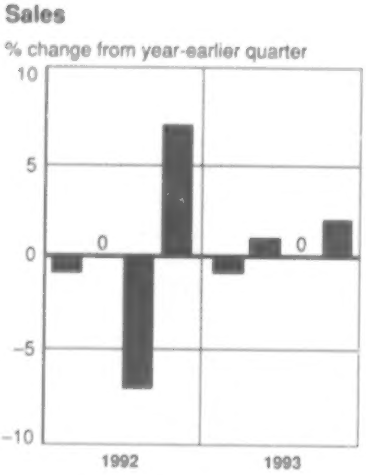
. . . and for full-year 1993

Sales				Earnings[a]			Profitability		
Rank 1993		$ Millions	Rank 1992		$ Millions	Rank 1992		Earnings as % of sales	Rank 1992
1	Dow Chemical	$18,060.0	1	Dow Chemical	$552.7	1	International Flavors	17.0%	1
2	Monsanto	7,902.0	2	Monsanto	460.0	3	Great Lakes Chemical	14.9	2
3	Union Carbide	4,640.0	3	American Cyanamid	348.1	2	Loctite	11.1	3
4	W. R. Grace	4,408.4	4	Air Products	280.8	4	Nalco Chemical	11.0	5
5	American Cyanamid	4,276.8	5	Great Lakes Chemical	272.8	5	Betz Laboratories	10.7	4
6	Air Products	3,341.5	6	W. R. Grace	234.4	7	Crompton & Knowles	9.3	6
7	Rohm and Haas	3,269.0	8	Arco Chemical	214.0	8	Air Products	8.4	6
8	Arco Chemical	3,192.0	7	Hercules	208.4	10	American Cyanamid	8.1	8
9	Hercules	2,800.0	9	International Flavors	202.5	9	Imcera	7.8	9
10	Morton International	2,539.0	12	Morton International	185.5	12	Hercules	7.4	14

Note: Based on 30 chemical companies listed on page 12. a After taxes.

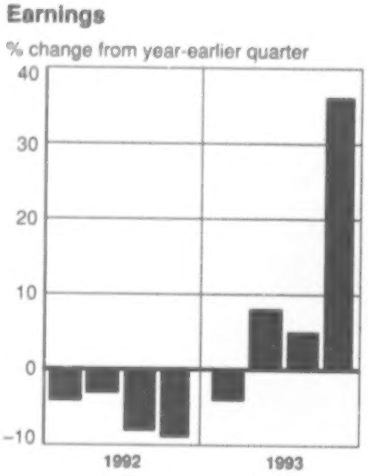
Chemical industry 1993 fourth-quarter results

- **Sales increased 2%**
- **Earnings climbed 36%**
- **Profitability was 4.8%**
- **Output rose 2.0%**
- **Prices up slightly**



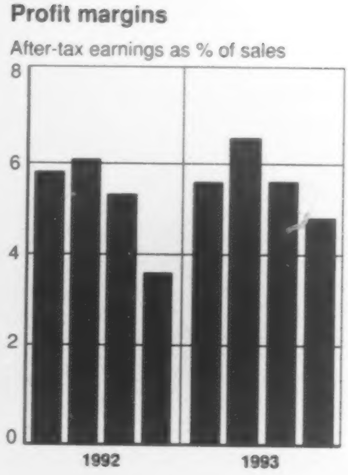
Sales

% change from year-earlier quarter



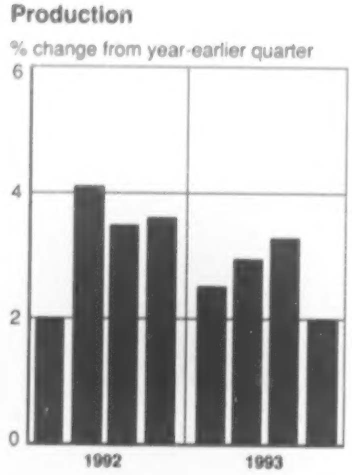
Earnings

% change from year-earlier quarter



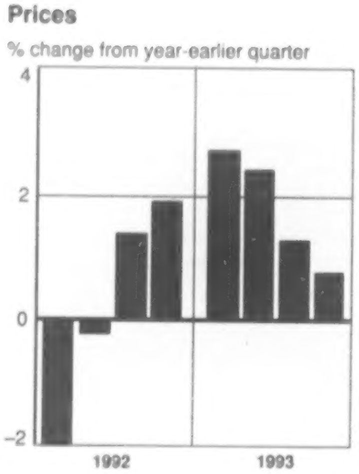
Profit margins

After-tax earnings as % of sales



Production

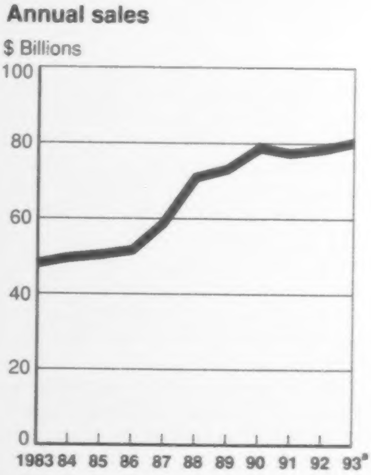
% change from year-earlier quarter



Prices

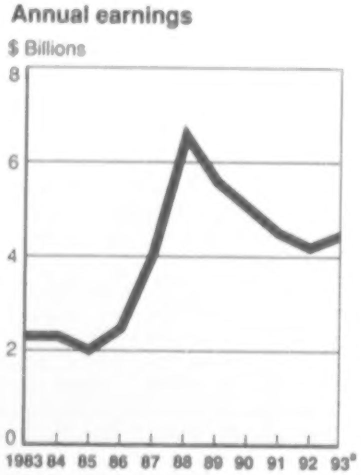
% change from year-earlier quarter

In 1993, sales pushed past $80 billion while earnings rose to almost $5 billion, driving profit margins higher



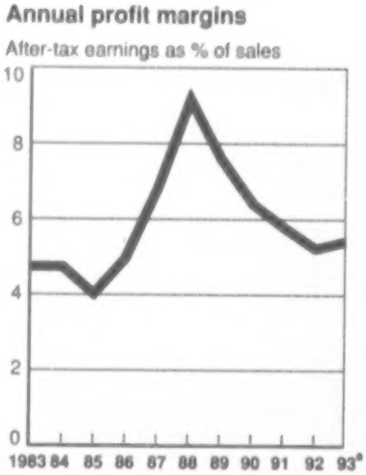
Annual sales

$ Billions



Annual earnings

$ Billions



Annual profit margins

After-tax earnings as % of sales

Note: All sales, earnings, and profit margin data are based on 30 chemical companies listed on page 12. a C&EN estimates for all 30 companies.

Chemical company earnings increased for both fourth quarter and full year

	FOURTH-QUARTER 1993						FULL-YEAR 1993					
	Sales	Earnings[a]	Change from 1992		Profit margin[b]		Sales	Earnings[a]	Change from 1992		Profit margin[b]	
	($ millions)		Sales	Earnings	1993	1992	($ millions)		Sales	Earnings	1993	1992
Air Products	$ 827.3	$ 75.1	2%	9%	9.1%	8.5%	$ 3,341.5	$ 280.8	2%	2%	8.4%	8.4%
American Cyanamid	985.4	40.1	3	−32	4.1	6.1	4,276.8	348.1	2	0	8.1	8.3
Arco Chemical	840.0	68.0	8	42	8.1	6.2	3,192.0	214.0	3	10	6.7	6.3
Betz Laboratories	168.4	15.2	−2	−24	9.0	11.6	684.9	73.1	−3	−11	10.7	11.6
Cabot	398.5	15.1	1	37	3.8	2.8	1,616.8	62.9	3	11	3.9	3.6
Crompton & Knowles	142.9	12.5	4	20	8.8	7.6	558.3	52.0	8	20	9.3	8.4
Dow Chemical	4,505.0	82.3	−5	202	1.8	0.6	18,060.0	552.7	−5	1	3.1	2.9
Ethyl	486.7	17.9	4	4	3.7	3.7	1,936.4	107.0	15	29	5.5	4.9
First Mississippi	115.9	3.1	11	def	2.6	def	457.3	5.7	−4	25	1.2	0.9
H. B. Fuller	247.8	6.9	1	−25	2.8	3.7	975.3	21.7	3	−39	2.2	3.8
Georgia Gulf	192.2	10.5	−3	17	5.5	4.6	768.9	42.2	−1	−9	5.5	5.9
BF Goodrich	488.3	1.9	22	−54	0.4	1.0	1,818.3	23.6	10	28	1.3	1.1
W. R. Grace	1,192.0	85.2	−2	15	7.1	6.1	4,408.4	234.4	2	16	5.3	4.7
Great Lakes Chemical	444.2	69.9	6	15	15.7	14.5	1,827.8	272.8	19	17	14.9	15.1
Hercules	714.7	58.3	3	39	8.2	6.0	2,800.0	208.4	−3	24	7.4	5.8
IMC Fertilizer	329.0	−3.6	67	def	def	1.5	1,074.1	−38.6[c]	11	def	def	5.0
Imcera	466.3	36.7	6	31	7.9	6.3	1,849.5	144.9	5	11	7.8	7.4
International Flavors	259.6	35.7	2	2	13.7	13.8	1,188.6	202.5	6	7	17.0	16.8
Loctite	152.2	14.8	4	−23	9.7	13.1	612.6	68.3	1	−5	11.1	11.9
Lubrizol	na	na	na	na	na	4.7	na	na	na	na	na	8.1
Monsanto	1,882.0	46.0	1	283	2.4	0.6	7,902.0	460.0	2	33	5.8	4.5
Morton International	690.9	53.7	27	57	7.8	6.3	2,539.0	185.5	18	28	7.3	6.7
Nalco Chemical	348.9	40.8	−3	0	11.7	11.4	1,389.4	152.7	1	5	11.0	10.5
Olin	598.4	9.2	8	171	1.5	0.6	2,422.6	40.2	2	−26	1.7	2.3
Petrolite	93.1	5.3	16	13	5.7	5.9	351.8	20.5	11	25	5.8	5.2
Praxair	613.0	40.0	−4	def	6.5	def	2,438.0	143.0	−6	15	5.9	4.8
Rohm and Haas	760.0	26.0	1	−10	3.4	3.8	3,269.0	181.0	7	−14	5.5	6.9
Stepan	na	na	na	na	na	4.1	na	na	na	na	na	3.6
Union Carbide	1,073.0	44.0	−10	132	4.1	1.6	4,640.0	165.0	−5	39	3.6	2.4
Witco	499.3	26.8	9	136	5.4	2.5	2,142.6	87.5	24	30	4.1	3.9
TOTAL[d]	**$19,514.8**	**$937.4**	**2%**	**36%**	**4.8%**	**3.6%**	**$78,543.8**	**$4,311.7**	**2%**	**8%**	**5.5%**	**5.2%**

a Earnings from continuing operations, excluding significant nonrecurring and extraordinary items. **b** Earnings as a percentage of sales. **c** Includes nonrecurring items. **d** For 28 companies reporting. **def** = deficit. **na** = not available.

ings, to a total of $937 million, came on an average sales increase of just 2% to $19.5 billion. This pushed up the aggregate profit margin for the group to 4.8% in the quarter from 3.6% in the fourth quarter a year earlier.

Perhaps the more important measure is the spread between growth in earnings and growth in sales. With sales increasing only 2% compared with the 36% increase in earnings from continuing operations, excluding major nonrecurring and extraordinary items, indications are clear that cost cutting has worked.

A good example of this was at Dow Chemical, where fourth-quarter earnings more than tripled to $82.3 million on a 5% decline in sales to about $4.51 billion

Ground rules for C&EN earnings analysis

C&EN's quarterly report on financial performance of the U.S. chemical industry contains data from the 30 largest U.S. basic chemical companies and from 19 oil and diversified companies, each with more than $200 million in annual chemical sales, plus nine pharmaceutical companies.

To be included in the table of basic chemical companies, a company must have at least 50% of its sales in chemicals. That is why DuPont, for example, is included in the table of diversified manufacturers.

In referring to chemical sales, C&EN means sales of those chemicals whose molecular composition has been changed in the course of manufacture. Hence, chemical sales include those of traditional categories of basic petrochemicals and inorganics, organic intermediates and inorganic compounds, polymers such as plastics and fibers, and agricultural chemicals and specialty derivatives.

In listing earnings, the report gives after-tax income for continuing operations before nonrecurring items and extraordinary charges. Foreign currency translations are included.

Earnings rose for oil, diversified, and drug companies in 1993

	FOURTH-QUARTER 1993						FULL-YEAR 1993					
	Sales	Earnings[a]	Change from 1992		Profit margin[b]		Sales	Earnings[a]	Change from 1992		Profit margin[b]	
	($ millions)		Sales	Earnings	1993	1992	($ millions)		Sales	Earnings	1993	1992
OIL AND GAS COMPANIES												
Amoco	$ 7,328.0	$ 464.0	1%	–15%	6.3%	7.6%	$ 28,622.0	$ 1,740.0	1%	18%	6.1%	5.2%
Ashland	2,571.6	58.4	1	136	2.3	1.0	9,899.1	149.0	0	262	1.5	0.4
Chevron	8,900.0	515.0	–17	–5	5.8	5.1	37,100.0	2,148.0	–7	38	5.8	3.9
Exxon	27,843.0	1,500.0	–10	7	5.4	4.5	110,977.0	5,280.0	–5	11	4.8	4.1
Mobil	16,859.0	602.0	–4	3	3.6	3.3	64,035.0	2,224.0	–1	49	3.5	2.3
Occidental Petroleum	2,020.0	17.0	–13	21	0.8	0.6	8,116.0	74.0	–4	–41	0.9	1.5
Phillips Petroleum	2,990.0	–33.0	–5	def	def	4.6	12,545.0	217.0	3	21	1.7	1.5
Shell Oil	5,155.0	152.0	–8	114	2.9	1.3	21,092.0	781.0	–3	76	3.7	2.1
Sun Co.	2,290.0	55.0	–14	67	2.4	1.2	9,417.0	193.0	–12	543	2.0	0.3
Unocal	1,965.0	70.0	–20	–23	3.6	3.7	8,344.0	347.0	–17	48	4.2	2.3
TOTAL	**$77,921.6**	**$3,400.4**	**–8%**	**–1%**	**4.4%**	**4.1%**	**$310,147.1**	**$13,153.0**	**–4%**	**27%**	**4.2%**	**3.2%**
DIVERSIFIED MANUFACTURERS												
AlliedSignal	$ 3,059.0	$ 178.0	0%	24%	5.8%	4.7%	$ 11,827.0	$ 658.0	–2%	22%	5.6%	4.5%
DuPont	9,251.0	329.0	1	96	3.6	1.8	37,098.0	1,953.0	–2	50	5.3	3.4
Eastman Kodak	4,480.0	204.0	0	–19	4.6	5.6	16,364.0	475.0	–1	–35	2.9	4.4
Engelhard	539.4	30.2	–1	8	5.6	5.1	2,150.9	102.2	–10	2	4.8	4.2
Ferro Corp.	265.3	15.8	2	–3	6.0	6.3	1,065.7	57.5	–3	–2	5.4	5.4
FMC	946.5	20.7	–6	–34	2.2	3.1	3,753.9	164.0	–6	–15	4.4	4.8
PPG Industries	1,378.2	98.1	–2	44	7.1	4.8	5,753.9	301.1	–1	–6	5.2	5.5
Tenneco	3,376.0	150.0	2	417	4.4	0.9	13,255.0	451.0	1	182	3.4	1.2
Vulcan Materials	282.0	20.6	4	1	7.3	7.5	1,133.5	88.2	5	–3	7.8	8.4
TOTAL	**$23,577.3**	**$1,046.4**	**0%**	**38%**	**4.4%**	**3.2%**	**$ 92,401.9**	**$ 4,250.0**	**–2%**	**22%**	**4.6%**	**3.7%**
PHARMACEUTICAL COMPANIES												
Abbott Laboratories	$ 2,228.0	$ 391.3	6%	12%	17.6%	16.6%	$ 8,407.8	$ 1,399.1	7%	13%	16.6%	15.8%
American Home Products	2,116.3	382.7	6	6	18.1	18.1	8,304.9	1,469.3	5	28	17.7	14.6
Bristol-Myers Squibb	2,992.8	565.8	6	7	18.9	18.7	11,412.7	2,269.1	2	8	19.9	18.9
Eli Lilly	1,800.8	332.4	9	7	18.5	18.8	6,452.4	1,347.1	5	63	20.9	13.4
Merck	3,000.8	674.2	15	11	22.5	23.4	10,498.2	2,166.2	9	–11	20.6	25.3
Pfizer	1,989.2	288.9	2	4	14.5	14.3	7,477.7	657.5	3	–40	8.8	15.1
Schering-Plough	1,066.4	188.9	7	13	17.7	16.9	4,341.3	825.0	7	15	19.0	17.8
Upjohn	926.3	155.9	–4	2	16.8	15.8	3,611.2	585.5	2	5	16.2	15.8
Warner Lambert	1,533.8	118.5	4	–14	7.7	9.3	5,793.7	645.0	4	0	11.1	11.5
TOTAL	**$17,654.5**	**$3,098.6**	**7%**	**7%**	**17.6%**	**17.5%**	**$ 66,299.9**	**$11,363.9**	**5%**	**5%**	**17.1%**	**17.1%**

a Earnings from continuing operations, excluding significant nonrecurring and extraordinary items where possible. b After-tax earnings as a percentage of sales. **def** = deficit

and where earnings for the year were up just 1% to $553 million, again on a 5% decline in sales to $18.1 billion. "Improved productivity in the fourth quarter and throughout 1993 compensated for the profit impact of lower sales," says Frank Popoff, the company's chairman and chief executive officer. "Interest rate management, reduced debt, and work process improvements helped us cut our net interest expense and research, promotion, selling, and administrative expenses by more than $400 million in 1993 compared to 1992. In addition, our capital spending and manufacturing costs were all lower in 1993. We will continue to make progress in this effort."

Union Carbide, whose earnings were up 132% for the quarter to $44 million and up 39% for the year to $165 million, tells pretty much the same tale. Robert D. Kennedy, Carbide's chairman and chief executive officer, says, "Earnings benefited from our cost reduction efforts, despite the continued worldwide downturn in the chemical industry. At the end of 1993, Carbide already had achieved more than $400 million in cost reductions and we are well on our way toward reaching our goal by the end of 1994. Continued attention to maintenance, inventory control, production and distribution activities, as well as the conclusion of streamlining activities in our corporate staff, information technology, finance, and engineering groups, should get us to our objective of a $575 million rate of savings by year's end."

And the cost cutting is not going to end at many companies. For instance, at W. R. Grace, president and chief executive officer J. P. Bolduc says, "The entire

Chemical earnings improve at most oil companies

If you want to know the state of petrochemicals, one of the best places to look is the chemical operations of oil companies. Made up largely of the big-volume organic building blocks of the chemical industry, the financial results of these operations tell more about the chemical economy than perhaps any other segment.

What these results are saying is that chemicals are helping oil companies to greatly varying degrees, but overall, petrochemicals are much stronger than they have been in some time.

For a group of eight oil companies with large chemical operations, these units delivered $331 million in earnings in the fourth quarter, up more than 600% from the same period in 1992. And for the full-year 1993, the $1.24 billion or so in earnings was almost double those in 1992.

Exxon, which has the biggest chemical operations of the oil companies, had earnings of $133 million from chemical operations in the fourth quarter, up 138% from the same period in 1992. But for the full year, its chemical earnings were down 9% to $410 million. The company says that in the fourth quarter, earnings from worldwide chemical operations benefited from lower operating expenses and increased sales of higher margin products despite excess industry capacity and weak economic conditions in many markets.

The same was true at Amoco, which boasted a more than fourfold increase in quarterly earnings to $83 million—higher sales volumes and margins in certain product lines and benefits associated with restructuring and cost-reduction efforts.

Shell Oil, which went from a $53 million loss in fourth-quarter 1992 to earnings of $67 million in fourth-quarter 1993, credited increased sales volumes of polymers and lower feedstock costs for commodity chemicals.

Not every company posted an earnings increase, however. Chevron, which went from a small $4 million profit in the fourth quarter of 1992 to an $8 million loss in 1993's fourth quarter, says the chemical results reflect the depressed state of the petrochemicals industry and especially that of olefins. Industry overcapacity and weak worldwide economies have held down product prices.

EARNINGS ON CHEMICAL OPERATIONS

	Fourth quarter			Full year		
$ Millions	1993	1992	% change	1993	1992	% change
Amoco	$ 83	$ 18	361%	$ 240	$–94	nm
Chevron	–8	4	nm	31	36	–14%
Exxon	133	56	138	410	451	–9
Mobil	1	4	–75	44	73	–40
Occidental	16	6	167	173	99	75
Phillips	30	10	200	75	41	83
Shell	67	–53	nm	220	12	1,733
Unocal	9	0	nm	43	23	87
TOTAL	**$331**	**$ 45**	**636%**	**$1,236**	**$641**	**93%**

nm = not meaningful.

organization is focused on improving our results in 1994. We will accomplish this through continuously improving how we operate—by moving faster into new global markets, reducing costs, introducing new products, and allocating resources only to those areas where returns will exceed the company's cost of capital."

It almost had to be cost cutting that boosted earnings in the fourth quarter, because many of the basic economic indicators of the chemical economy just didn't show that much life. For instance, prices were up less than 1% for chemicals and allied products in the quarter and production rose only about 2%.

Shipments of chemicals and allied products in the fourth quarter increased 4% over the same period the year before—about the same rate they increased for the entire year. And shipments of industrial chemicals, up 1.7% in the quarter, registered lower growth than the 2.9% seen for the year as a whole.

Prices were on the minds of many chemical company executives, among them J. Lawrence Wilson, chairman and chief executive at Rohm and Haas. Wilson says: "We are pleased with our volume growth during tough economic times, but we are not happy with the results that pricing pressures and currency movements brought to the bottom line. We expect better earnings in 1994, but until European and Japanese economies recover and our internal cost-reduction measures are fully implemented, we do not expect the dramatic earnings improvement recorded during previous economic recoveries"

As evidenced by Wilson's comments, foreign markets and their economic problems are still very much on the minds of industry executives. At Cabot Corp., chairman and chief executive officer Samuel W. Bodman says: "Our income continues to benefit from worldwide cost reduction efforts but we remain concerned that the European and Japanese economies are still quite sluggish."

At DuPont, chairman Edgar S. Woolard notes that chemicals and specialties businesses benefited from lower costs, "but this was mitigated somewhat by weak economic conditions in Europe." Woolard adds, "We will continue with strong efforts to improve productivity and raise revenues, so that our businesses grow faster than the growth anticipated in global economies."

Despite the problems in pricing, demand, and foreign economies, many chemical producers are optimistic about what lies ahead. Perhaps the most sanguine is Witco's chairman and chief executive officer, William R. Toller: "We are starting 1994 with an optimistic outlook and great enthusiasm as we aggressively operate in a marketplace with our new structure in place. In 1993, all segments of our business performed well in a tough economic environment, including in Europe. We made satisfying progress in meeting our goals of international expansion, increasing dividends, and concentration of our resources on core businesses as our divestment plans moved forward."

Much of what Toller says can be said for most of the U.S. chemical industry. With that in mind, barring any major economic dislocation, most chemical executives agree that 1994 seems to be looking better than any year in the recent past. ☐

Europe's petrochemical outlook remains bleak

The problems of Western Europe's petrochemical industry—overcapacity, high fragmentation, bleak profitability, increasing foreign competition—continue to point to a bleak outlook. Indeed, according to Roger C. M. Longley, a director for consultant Chem Systems Ltd., London, recent efforts to resolve some of the industry's structural problems in Western Europe have fizzled out, leaving companies facing ever tougher decisions on their own.

Speaking at the consulting firm's annual seminar on petroleum and petrochemical economics, held in London, Longley said that petrochemical companies' problems must be solved by internal actions, not by reliance on a general economic upturn. An upturn may help, but it will be no cure-all.

The chemical industry goes through cycles dependent upon those of the general economy, he points out. But cyclic behavior hides the underlying problems. "It distorts or conceals creeping uncompetitiveness and failing to invest in key businesses. A business only stays profitable if costs are continuously reduced to match market performance, and costs, rather than capacity issues, should drive restructuring in the sector."

Given the West European industry's relatively high cost structure, there is no particularly compelling case for the region to be an expanding area for ethylene derivatives. Nor will the next few years' worth of demand come from the area.

Total global ethylene demand is forecast to grow from 62 million metric tons in 1992 to 89 million metric tons by 2000, while total global capacity for ethylene production will reach 99 million metric tons worldwide by the end of the decade, according to consultant Martin Rock, also with Chem Systems. However, demand in Western Europe is expected to grow more slowly, from 16 million metric tons in 1992 to 19 million metric tons in 2000.

This means that the industry will continue to face structural problems requiring urgent actions—actions that should be taken but which are hampered by other factors.

Among these problems are the effects of company culture, Longley says. For example, a company might need to cut capacity or even get out of a nonstrategic business, but may procrastinate because of sentimental attachment to the activity or because of a "we invented it" attitude. And if the chemicals culture gets out of sync with that of a parent, other problems arise. Chem Systems, he says, is seeing more "dissatisfaction of oil companies with their petrochemical subsidiaries. This goes beyond short-term dissatisfaction with results: it is becoming a great cultural divide between 'group' and 'chemicals' cultures.' "

He also cites financial constraints hindering positive action. "Diversified companies must allocate funds to the part of their portfolios that they see as most deserving, which may make it impossible to fulfill a petrochemical strategy that is opti-

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December 19–20, 1994

Monday, December 19
Heinz Staab, Heidelberg, "From Paracyclophanes to Photosynthesis Models"
Masashi Tashiro, Kyushu University, "Synthesis and Chemistry of [2.2]metacyclophanes"
Emanuel Vogel, University Koln, "From 1,6-Methano[10]annulene to Metalloporphyrinoids"
Peter Vollhardt, UC-Berkeley, "The Phenylenes: A Testing Ground for the Origin of Delocalization in Benzene"
Horst Prinzbach, University Freiburg, "New Aspects in the Chemistry of Hydrocarbon Cages"
Leo Paquette, Ohio State Univ., "Unleashing the Synthetic Potential of Strained Ring Systems"
Francois Diederich, ETH, "Synthetic Molecular and Polymeric Allotropes of Carbon"
G. K. Surya Prakash, USC, "Functionalizing Hydrocarbons with Fullerenes"

Tuesday, December 20
Armin de Meijere, Georg-August-U, Gottingen, "Small Rings Galore: New Star and Cage Hydrocarbons"
Teruaki Mukaiyama, Science University, Tokyo, "Oxygenation of Olefins with Molecular Oxygen"
Robert Moriarty, University Illinois, Chicago, "Hypervalent Iodine Syntheses in the Cubyl System"
Peter Stang, University Utah, "Bis-Cyclopentenes, Cyclopentenones and Conjugated Enynes via Iodonium Chemistry"
Lawrence Scott, Boston College, "Novel Syntheses and Reactions of Polycyclic Aromatic Hydrocarbons at Inordinately High Temperatures"
Mordecai Rabinovitz, Hebrew University, "The Spatial Structure of Polycyclic Carbanions"
Clarence Chang, Mobil, NJ, "Influence of Intrazeolitic Environment on Electrophilic Aromatic Substitutions"
Jule Rabo, UOP, Ill, "The Role of Structure in Acid Function of Zeolites Effecting Hydrocarbon Transformations"
George A. Olah, USC & **Dale Williams,** Texaco, Houston, "Modified HF Catalyzed Environmentally Safe Isobutane-Isobutylene Alkylation"

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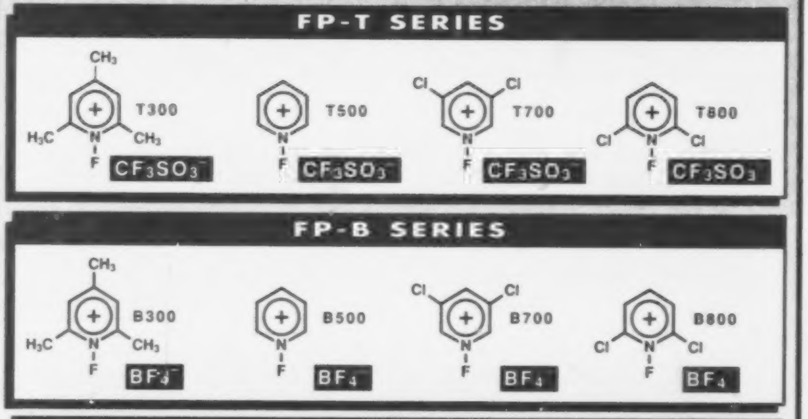

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CIRCLE 3 ON READER SERVICE CARD

mum on a stand-alone basis. Countercyclic investment is very rarely made because of this and is made worse by short-term views in a business that ideally needs a 10-year investment cycle." Furthermore, companies contemplating joint ventures know that they lose ownership of assets and control of cash flow, which may damage their financial ratios, so they may elect not to enter the venture.

The industry can change, however: Witness the revitalization of industry segments in the U.S. because of investors Lord Hanson, Jon M. Huntsman, and Gordon A. Cain. "There are some signs that restructuring in Europe will bring in some different management styles," Longley predicts.

One reason Western European oil companies may be dissatisfied with their petrochemical operations, suggests Chris Brown, a Chem Systems senior consultant, is because refiners faced many of the same problems that petrochemical producers did early in the 1980s, but made difficult and painful decisions to restructure that have paid off.

Middle East, Asia will lead growth in ethylene demand

Millions of metric tons	1992	1995	2000	% annual change 1992–2000
Western Europe	16	17	19	2.2%
North America	21	23	26	2.7
Eastern Europe	6	7	10	6.6
Middle East/Africa	3	4	8	13.0
Latin America	3	4	5	6.6
Japan	6	7	7	1.9
East Asia/Oceania	7	9	14	9.1
TOTAL	**62**	**71**	**89**	**4.6%**

Source: Chem Systems Ltd

Brown contends that European refiners have led the world in trying to correct overcapacity and poor profitability. The number of refineries dropped to just over 100 in 1993 from about 150 in 1980, with a typical staffing level of about 500 employees today, compared with staffing levels that frequently were well over 1,000 per refinery in the 1980s.

What's more, he and Longley agree, refiners have managed to be relatively profitable into the 1990s. Petrochemical operating rates now are roughly the same as refinery operating rates, Longley points out. "But refiners can make money at those rates, and petrochemicals can't," he says. An operating rate of 88% in petrochemicals means the most inefficient producers are sustaining losses, and the most efficient are barely breaking even. In contrast, at the same rates, the least efficient refiners are breaking even, and the most efficient are getting a good return.

Despite the disenchantment of oil companies with their chemical operations, benefits of oil refinery/petrochemical integration do exist, Brown notes. "You can quantify integration benefits for petrochemicals of about $70 per [metric] ton of ethylene; there are similar benefits for refiners."

Patricia Layman

DEFENSE ACQUISITION SCHOLARSHIP PROGRAM

SCHOLARSHIPS FOR GRADUATE STUDIES LEADING TO MASTERS DEGREES
IN BUSINESS ADMINISTRATION, PHYSICAL SCIENCE, ENGINEERING, MANAGEMENT OF TECHNOLOGY, AND PUBLIC ADMINISTRATION with a concentration in SCIENCE, TECHNOLOGY, AND PUBLIC POLICY

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Application Deadline:
March 22, 1994

CIRCLE **16** ON READER SERVICE CARD

Clinton's 1995 Budget Proposal Calls for Increases in R&D Funding

But in a tightly constrained budget, the focus is on research that addresses national goals

David J. Hanson, Bette Hileman, Wil Lepkowski, Janice R. Long, and **Pamela S. Zurer,** C&EN Washington

The first reduction in federal discretionary spending that almost anyone can remember, and a $58 billion reduction (at least on paper) in the federal deficit are the hallmarks of the fiscal 1995 budget that President Bill Clinton submitted to Congress on Feb. 7.

Nevertheless, the budget proposals call for a 3% rise to $73 billion in total federal R&D spending, which fell 2% from 1993 to 1994. The Clinton Administration had less than three months to prepare its first budget, which was submitted to Congress in early April of last year. It's had a year to work on the 1995 proposal, and it shows.

In line with Clinton's emphasis on research that will benefit both the quality of life in the U.S. and the nation's competitive position, funding for applied R&D would rise 4% to $56.9 billion in fiscal 1995, following a 3% decline in the current fiscal year. Funding for basic research would increase 2% to $14.1 billion, on the heels of a 3% rise in fiscal 1994. Funding for R&D facilities would drop once again, down 22% to $2.0 billion.

This budget may mark the end of the tug-of-war between so-called big and little science. Missing from its pages is any funding—except money for shutdown—for the Superconducting Super Collider, which Congress killed last year, and funding for the space station is essentially frozen at about $2 billion.

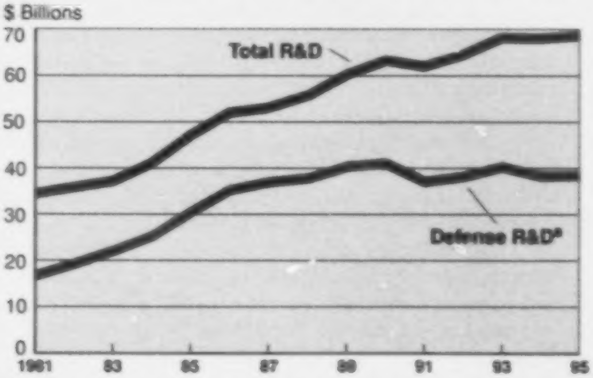
The R&D part of the Administration's budget proposal drew a wide variety of responses. Two examples:

Rep. George E. Brown Jr. (D.-Calif.), chairman of the House Committee on Science, Space & Technology, says, "The good news on deficit reduction heralds tough times ahead for the nation's R&D investment. The stringency of the budget caps has seriously squeezed funding for a number of worthwhile science programs in fiscal 1995, and the long-term outlook for many science and R&D budgets is very grim." Brown's committee has budget authority over all R&D programs except those carried out by the departments of Agriculture, Defense, and Health & Human Services.

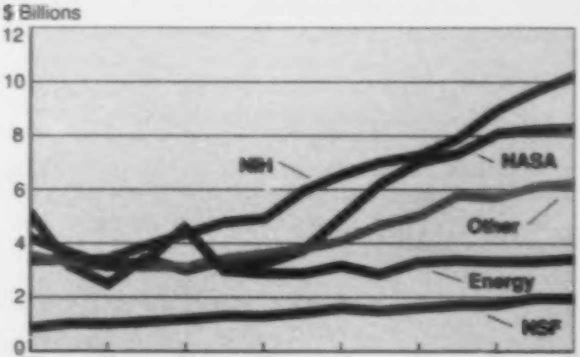
On the other hand, Cornelius Pings, president of the American Association of Universities (AAU), says: "I think we have to be very pleased with the proposed increases in the research budget given what's going on in the federal arena, with some departments and agencies actually facing cuts. Sure, we could use more, but on balance this is very good news."

AAU's members, however, are troubled by the President's proposal to seek a "pause" in indirect cost payments to universities and other research institutions in fiscal 1995. Under the suggested plan, the dollar amount each university re-

Despite end of Cold War, defense still consumes over 55% of total R&D funds . . .



. . . while NIH continues to account for over 30% of nondefense R&D funds



Note: Outlays. Funding for R&D facilities not included. a Includes military-related programs of the departments of Defense and Energy. **Source:** Office of Management & Budget

Fiscal 1995 federal R&D budget increases 3% . . .

$ Millions	1995[a]	1994[a]	1993[b]	% change 1994–95
BY AGENCY[c]				
DOD	$36,971	$35,538	$38,617	4%
Health & Human Services	11,484	11,033	10,336	4
NASA	8,597	8,493	8,090	1
Energy	6,052	6,054	5,827	0
NSF	2,220	2,026	1,882	10
Agriculture	1,394	1,393	1,335	0
Commerce	1,204	919	667	31
Transportation	692	617	578	12
EPA	582	536	508	9
Other agencies	1,833	1,876	1,910	–2
BY FUNCTION				
Conduct of R&D	**71,029**	**68,484**	**69,750**	**4**
Applied R&D	**56,917**	**54,693**	**56,388**	**4**
Defense[d]	38,296	36,923	40,004	4
Civilian	18,621	17,770	16,384	5
Basic research	**14,112**	**13,790**	**13,362**	**2**
Civilian	12,880	12,578	11,951	2
Defense[d]	1,232	1,212	1,411	2
R&D Facilities	**2,016**	**2,589**	**2,728**	**–22**
TOTAL	**$73,045**	**$71,072**	**$72,478**	**3%**

. . . and emphasizes high-priority, 'strategic' investments

$ Millions	1995[a]	1994[a]	1993[b]	%change 1994–95
University research support	$12,156	$11,719	$11,674	4%
International space station	2,121	2,104	2,262	1
Dual-use technology	2,148	2,011	1,705	7
Manufacturing technology extension programs	2,061	1,871	18	10
Global-change research	1,794	1,446	1,338	24
Transportation research	1,180	944	655	25
High-performance computing & communications	1,154	938	772	23
Technology transfer	865	551	384	57
Human genome project	241	199	169	21

Note: Budget authority. Strategic items contain double counting (they should not be summed), reflecting the leveraged nature of these investments. **a** Estimate. **b** Actual. **c** Does not include facility funding. **d** Includes military-related R&D programs of the departments of Defense and Energy. **Source:** Office of Management & Budget

ceives for overhead reimbursements would be capped at the level they recoup in fiscal 1994.

" 'Pause' is an interesting euphemism," Pings says. "It's not really a saving but a shifting of costs to universities. It's an unfortunate proposal whose full impact has not been worked out. It has the curious feature of punishing success: Funds will be denied to those who are successful in increasing their research base."

Pings points out that a substantial fraction of indirect cost reimbursements pays for research facilities, many of which are in critical need of upgrading. "We haven't been successful in conveying that we can't simply do research out on the lawn," he says. "I suspect the policy is going to erode what little discretionary funding universities have, most of which now goes to get new faculty started."

AAU plans to oppose the proposal, Pings says. The organization will try to convince Congress' appropriations committees that the policy will impose hardships on universities while creating new bureaucracies both in government and on campus.

In the following sections, C&EN provides a closer look at the budgets proposed for most of the various federal agencies that support research, particularly chemical research, activities.

National Science Foundation. With a 6% increase over its $3.0 billion total for fiscal 1994, NSF has no reason at all to complain about the treatment given it by the Clinton Administration. The Administration has said all along that its policy is to protect basic science. So the rise to a total of $3.2 billion really comes as no surprise to budget watchers. "A very good budget, in a very tough budget year," is how NSF director Neal F. Lane put it in his briefing to the press on Feb. 7.

NSF's keyword this year is "strategic," and its aim—mandated by Congress—is to place 60% of its research program under that rubric. Thus, it stresses the strategic areas of advanced manufacturing technology; advanced materials processing; biotechnology; environmental research; global-change research; high-performance computing and communications; and science, math, engineering, and technology education. Together they amount to $2.11 billion.

The total can be misleading, however, because the categories overlap. Advanced manufacturing technology, for example, can have a substantial biotechnology component; high-performance computing is applicable to the modeling and instrumentation challenges of global-change research.

Chemistry is one of the divisions benefiting from NSF's focus on strategic initiatives (C&EN, Feb. 7, page 16). Just before the proposed 1995 budget was announced, the division received an additional $2 million for fiscal 1994 for environmental chemistry programs. That extra money, which was shifted from other divisions within the Mathematical & Physical Sciences (MPS) Directorate, increased the chemistry division's budget for 1994 to $121 million.

The division's proposed budget for fiscal 1995 would increase 7% to $130 million. All of the $6.5 million increase for research is targeted toward strategic research areas, says acting division director John B. Hunt, including an additional $2 million for advanced manufacturing research and $3 million for environmental chemistry, which includes global-change research.

"We may have trouble identifying enough proposals in environmental chemistry to spend the money," Hunt told a recent gathering of government staff from agencies that fund chemical research. "We're a little bit uncomfortable, but it's a kind of discomfort I bet most of you would like to have."

NSF's only decrease would come in the highly political category of bricks and mortar—or academic research infrastructure. The subject has been debated for years, with Congress usually appropriating increases and the executive branch refusing them. Last year, NSF asked for $55 million, but Congress appropriated $100 million. For fiscal 1995, NSF is once again asking for $55 million. Lane says he knows the infrastructure needs of universities are critical, but that research funds are more important and that the Administration is looking deeply into some long-term solutions to the problem. Nothing new about that.

One of the peculiarities of NSF's budget is the outsized increase in funding for global-change research. That figure would rise from an already substantial $142 million to almost $208 million. High-performance computing and communications, another big NSF initiative, would rise more modestly but still impressively, from $267 million to $329 million. Environmental research is another major NSF winner, rising 8% from $144 million to $156 million.

Why should those areas deserve a much larger increase than, say, biotechnology or social and behavioral research? Washington policy observers say the answer is simple: They are Vice President Al Gore's favorite subjects. Even the seemingly substantial 15% rise in social behavioral science—from $70.6 million to $84 million—largely goes for studies related to the social impact of global change.

Funding for science and math education, which has grown like crazy over the years at NSF, virtually levels off—rising only 3% to $586 million. Lane says it's time to pause and take a look at how well the many programs within that activity are working out. Another sector that NSF has stressed in recent years is the engineering and science and technology research centers. However, the total funding remains about the same ($110 million to $111 million) so no new projects will be funded unless some existing ones are not renewed.

National Institutes of Health. The President's budget for fiscal 1995 includes $11.5 billion dollars for NIH, an increase of over $500 million, 5% more than the current fiscal year. That's not nearly as high as many in the biomedical research community would like—the Federation of American Societies of Experimental Biology, for example, had recommended a 9% raise for NIH—but it is a respectable showing in light of the pressures on the federal budget.

In the competition for funding, NIH benefits from the clear links between its programs and improvements in human health. "Basic science research and other research in NIH are very much a part of the President's plan for health care reform," says Donna E. Shalala, Secretary of the Department of Health & Human Services (HHS). "Included in our definition of prevention is our investment in NIH and basic sciences in general."

Shalala also credits NIH director Harold E. Varmus with the relative success of the NIH budget. "The extraordinary leader we've attracted to NIH is keeping everyone's feet to the fire," she says.

As with other federal agencies, a growing part of NIH's portfolio is being focused on areas the budget calls strategic or high need. More than $2 billion of NIH's proposed budget is targeted at AIDS, breast cancer and other women's health research, the human genome project, minority health, tuberculosis, and high-performance computing.

AIDS research at NIH would increase 6% over the fiscal 1994 level to $1.4 billion. For the first time, funding for AIDS research at NIH is not being assigned directly to each individual institute. Instead, under a scheme made law in last summer's NIH Revitalization Act (C&EN, June 7, 1993, page 5), it will be appropriated as a lump sum to the Office of AIDS Research. That recently expanded office will transfer the monies to the individual institutes in accordance with a supposedly comprehensive plan.

Glossary of budget terms

Budget authority. The authority provided by federal law enacted by Congress to incur financial obligations that will result in outlays.

Fiscal year. The fiscal year is the government's accounting period. It begins Oct. 1 and ends Sept. 30 and is designated by the calendar year in which it ends.

Obligations. Binding agreements that will result in outlays, immediately or in the future. Budgetary authority must be available before obligations can be incurred legally.

Outlays. Payments for obligations incurred under Congressionally granted budget authority generally made by issuance of checks on the Treasury. Outlays during any fiscal year may be made for obligations incurred in prior fiscal years or in the same fiscal year.

Note: The R&D numbers supplied by individual agencies frequently differ from those used by the Office of Management & Budget in preparing its analysis of total federal R&D funding.

NIH's National Center for Human Genome Research would get $152 million in fiscal 1995, a whopping 18% above this year's spending level. Most of the $23 million increase is slated for NIH's intramural program, where the center's director, Francis S. Collins, has established a growing laboratory.

The total number of research project grants supported under NIH's proposed budget would decrease slightly in 1995, from 23,985 to 23,891. But the number of new and competing renewal grants would shoot up by more than 1,000 to 7,293. That would be the highest level of new grants ever funded by NIH.

That surprisingly large increase results from an unusual nexus in the normal grant cycle, according to Marvin Cassman, acting director of the National Institute of General Medical Sciences (NIGMS). In the late 1980s, NIH moved toward longer grant periods, averaging close to five years in length. But in 1990, Congress directed the agency to aim for a four-year average, to free up a greater portion of funds each year.

"All the grants we awarded for five years in 1990 plus all the ones we awarded for four years in 1991 will be turning over in 1995," Cassman says. A larger portion of the budget will thus be available for new and competing grants.

NIGMS, the largest single source of chemistry funding within NIH, would receive a 4% budget increase in 1995 to $907 million. Within NIGMS, funding for the cellular and molecular basis of disease program would increase 4% to $254 million; the biophysics and physiological sciences program, 4% to $197 million, including $25 million for AIDS; and pharmacology and biorelated chemistry, 3% to $131 million.

"I think we did very well," Cassman says about NIGMS. "You've got to look at the increases in the context of the whole federal government. Given the constraints on the budget, it could have been a lot worse, and it was for a lot of agencies. You are not going to hear me complaining."

Energy. The biggest story in energy research has to be the demise of the Superconducting Super Collider. Funded at $640 million in fiscal 1994, the Department of Energy (DOE) is asking for only $180 million next year to continue termina-

NSF's budget is up just 6% overall . . .

$ Millions	1995[a]	1994[b]	1993[c]	% change 1994–95
Mathematical & physical sciences	$ 657.7	$ 619.8	$ 585.9	6%
Education & human resources	586.0	569.6	505.1	3
Geosciences	443.1	403.9	381.6	10
Biological sciences	313.9	288.8	271.3	9
Engineering	320.4	295.2	256.1	9
Computer & information science & engineering	273.5	240.6	215.6	14
U.S. polar research program & logistics	225.4	220.7	244.2	2
Salaries & expenses	130.7	118.3	110.8	10
Social, behavioral & economic sciences	112.6	98.3	90.7	15
Academic research infrastructure	55.0	100.0	49.8	–45
Major research equipment	70.0	52.0	34.1	35
Other	11.6	10.7	4.7	8
TOTAL	**$3,199.9**	**$3,017.9**	**$2,749.9**	**6%**

. . . with funding for the 'hard' sciences up 8% . . .

$ Millions	1995[a]	1994[b]	1993[c]	% change 1994–95
Mathematical & physical sciences	**$ 657.7**	**$ 619.8**	**$ 585.9**	**6%**
Materials research	185.5	176.1	164.5	5
Physics	141.7	133.7	128.3	6
Chemistry	129.9	121.4	112.3	7
Astronomical sciences	111.9	106.4	103.2	5
Mathematical sciences	88.7	82.2	77.6	8
Geosciences	**443.1**	**403.9**	**381.6**	**10**
Ocean sciences	207.9	188.9	179.3	10
Atmospheric sciences	147.9	134.4	126.5	10
Earth sciences	87.3	80.6	75.8	8
Biological sciences	**313.9**	**288.8**	**271.3**	**9**
Molecular & cellular biosciences	91.0	85.1	81.1	7
Integrative biology & neurosciences	83.7	77.9	74.3	7
Environmental biology	83.3	74.8	70.2	11
Biological instrumentation & resources	55.9	51.0	45.7	10
TOTAL	**$1,414.7**	**$1,312.5**	**$1,238.8**	**8%**

. . . and that for chemical programs up 6%

$ Millions	1995[a]	1994[b]	1993[c]	% change 1994–95
Materials research	**$185.5**	**$176.1**	**$164.5**	**5%**
Project support	95.3	88.4	80.5	8
Science & engineering centers	55.3	54.8	51.5	1
National facilities & instrumentation	34.9	32.9	32.5	6
Chemistry	**129.9**	**121.4**	**112.3**	**7**
Research project support	109.4	102.9	95.6	6
Instrumentation & infrastructure	20.5	18.5	16.7	11
Engineering	**61.9**	**59.2**	**54.9**	**5**
Chemical & transport systems	**38.4**	**37.1**	**34.5**	**4**
Fluid, particulate & hydraulic systems	10.2	9.9	9.2	3
Chemical reaction processes	10.2	9.9	9.3	3
Interfacial, transport & separations processes	9.6	9.2	8.6	4
Thermal systems	8.4	8.1	7.4	4
Bioengineering & environmental systems	**23.5**	**22.1**	**20.4**	**6**
Bioengineering	17.1	16.0	14.6	7
Environmental & ocean systems	6.4	6.1	5.8	5
Biochemistry & molecular structure & function	**36.1**	**33.9**	**32.7**	**6**
TOTAL	**$413.4**	**$390.6**	**$364.4**	**6%**

Note: Obligations. **a** Estimate. **b** Current plan. **c** Actual. **Source:** National Science Foundation

tion of the project. There has been no decision yet on what will be done with the research buildings and facilities already in place at its site in Texas.

That steep, 72%, fall in SSC facility funding allows DOE to hold actual research funding even at $6.1 billion in a total R&D budget that's down 5% to $6.6 billion. Some programs would increase—as in high-energy physics, where funding is up 1% to $622 million; $140 million is being requested to support university and laboratory-based groups conducting experimental and theoretical research. The department is asking for $254 million for facility operations and $58.2 million for improving physics technology.

Basic energy sciences, however, is facing a major budget cut in fiscal 1995. This program has a proposed budget of $741 million, down $49.1 million from 1994. Among the individual programs, funding for materials science research is down $2.8 million to $274 million; chemical sciences is down $7 million to $162 million; engineering and geosciences is down $1.1 million to $36.8 million; energy biosciences research is down $700,000 to $26 million; and advanced energy projects are down $300,000 to $11.1 million. Only funding for applied mathematical sciences would rise, up $3.2 million to $109 million.

Robert S. Marianelli, director of the division of chemical sciences in DOE's Office of Basic Energy Sciences, says the division's extramural grants program will remain essentially healthy in fiscal 1995. And support for major research facilities such as the Advanced Light Source at Lawrence Berkeley Laboratory will continue. However, grants to principal investigators at DOE's national labs are being cut back under the division's shrinking budget.

Research and development for the nation's defense programs is part of DOE's responsibility. The 6% drop to $1.2 billion in the fiscal 1995 budget request for this work reflects the end of the Cold War and changing priorities. This funding level will maintain core research competency at the weapons labs through research on safety and reliability of the weapons stockpile, on dismantling efforts, on nonproliferation, and on pollution prevention studies. The proposed budget also will keep DOE ready to restart underground nuclear testing within six months, if directed to do so by the President.

Marianelli points out that the enormous environmental cleanup problems that DOE faces at its nuclear installations across the country will continue to be a major force shaping the department's budget strategies. DOE has requested a total of $6.3 billion for environmental management and sees the need for basic re-

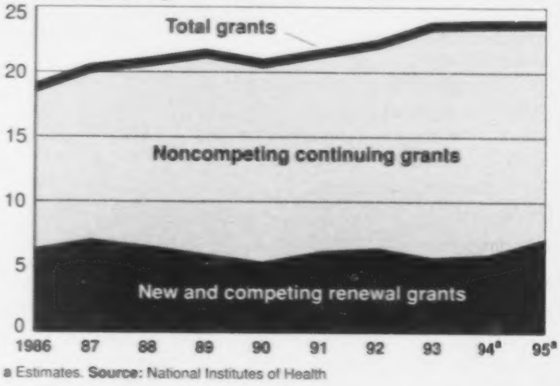
At NIH, R&D at most institutes, including General Medical Sciences, rises only 4%

$ Millions	1995[a]	1994[a]	1993[b]	% change 1994–95
National Institutes	$10,435	$10,009	$ 9,483	4%
Cancer	2,190	2,082	1,978	5
Heart, Lung & Blood	1,325	1,278	1,215	4
Allergy & Infectious Diseases	1,121	1,066	984	5
General Medical Sciences	907	876	832	4
Diabetes & Digestive & Kidney Diseases	743	716	681	4
Neurological Disorders & Stroke	654	631	600	4
Mental Health	638	613	583	4
Child Health & Human Development	581	555	528	5
Drug Abuse	444	425	403	4
Aging	435	420	400	4
Eye	301	290	275	4
Environmental Health Sciences	274	264	251	4
Arthritis & Musculoskeletal & Skin Diseases	231	223	212	4
Alcohol Abuse & Alcoholism	193	186	176	4
Dental Research	176	170	161	4
Deafness & Other Communication Disorders	169	163	155	4
Nursing Research	53	51	49	4
National Center for Research Resources	**351**	**332**	**313**	**6**
Office of the Director	**260**	**234**	**192**	**11**
National Center for Human Genome Research	**152**	**129**	**106**	**18**
National Library of Medicine	**139**	**120**	**104**	**16**
Other[c]	**137**	**133**	**132**	**3**
TOTAL	**$11,474**	**$10,957**	**$10,330**	**5%**

a Estimate. b Actual. c Includes Fogarty International Center and buildings and facilities. **Source:** National Institutes of Health

Number of new NIH grants will reach record high in 1995

Research project grants awarded, thousands



a Estimates. **Source:** National Institutes of Health

search to address the issues. "When you don't have answers to the problems that face you, you need fundamental research," he says.

National Institute of Standards & Technology. NIST is the biggest winner of all in the fiscal 1995 R&D budget. NIST can be seen as the agency where the Administration's ambitious technology policy is being tested out, and it is undergoing a revolution under its new director, Arati Prabhakar. Where NSF is trying to become more strategic, NIST always has been.

As promised by Clinton in his campaign, NIST's budget has more than doubled from its fiscal 1993 level, rising from $359 million then, to $574 million in fiscal 1994, to $921 million in the fiscal 1995 request. What is significant for NIST is that, for the first time, its extramural spending exceeds its intramural activities—$517 million to $304 million. Another $100 million is targeted for replacement of obsolete laboratories in Gaithersburg, Md., and Boulder, Colo.

At the moment, NIST is the Administration's darling among the federal laboratories. Its assignment is to set the pace for ways the government can interact with industry. Its successes, and especially its failures, will be closely watched. More than half of NIST's $347 million increase will go for its Advanced Technology Program (ATP) and its Manufacturing Extension Partnership (MEP).

Under the budget request, ATP receives $450 million, money that will be matched by grantees, for its program of funding for various areas of research, development, and technology. Its method is modeled after the Defense Department's Advanced Research Projects Agency (ARPA), which works closely with industry to support development of advanced technologies important to the military. In a word, NIST is ARPA gone civilian.

The other half of the new, externally directed NIST is its MEP, which is asking Congress for $67.5 million, or $27.7 million more than in fiscal 1994. MEP is NIST's extension service, as it were, designed to work with state programs to help some of the country's 370,000 small- and medium-sized businesses upgrade their manufacturing processes. The Administration is aiming for a network of 100 manufacturing technology centers by 1997.

NIST has always been best known for its core in-house research work related to key technologies and development of measurement standards. Over the years, the budget for this research has hardly moved. But 1995's $79 million increase (to $304 million), plus the $100 million in construction, will help NIST restore some of the lost ground. Within that, NIST's chemical science and technology laboratory budget increases from $22.4 million to $30 million. Funding for materials science and engineering increases from $45 million to $60.2 million.

Defense. Most of the requested increases in the Defense Department's research, development, test, and evaluation budget are earmarked for testing and development of weapons systems.

Science and technology programs would increase about 4% to about $8.1 billion in fiscal 1995, accounting for about 22%

of Defense's total R&D request. Of this, $3.0 billion is for exploratory development, $3.9 billion for advanced development, and about $1.2 billion for basic research. These numbers do not include the Ballistic Missile Defense Office, formerly the Star Wars defense program, which is requesting nearly $3.0 billion, a $363 million increase.

One Defense agency getting increased funding across all areas is ARPA. Funded at nearly $2.6 billion in fiscal 1994, the Administration is seeking a $100 million increase for fiscal 1995. Other defense offices receiving significant R&D increases are the Defense Logistics Agency and the Defense Mapping Agency, where the increases are likely to go to modernizing computer systems and information technology.

The Defense Department is also paying close attention to the link between the military and economic components of the nation's security. In that light, it is allocating $2.1 billion for development of dual-use technologies—those that have both military and civilian applications—in fiscal 1995. Portions of the dual-use program include reinvestment initiatives to boost R&D of critical dual-use technologies, as well as efforts to commercialize these technologies.

Also, Defense will set up programs to assist small manufacturers in upgrading their capabilities to meet commercial and defense needs, and it plans electronics and materials initiatives to support industry research for technologies ranging from high-definition computer systems to composite materials manufacturing.

As at other agencies, the environment is becoming a major focus of research at the Defense Department. For example, the Pentagon has directed the Air Force Office of Scientific Research (AFOSR) to emphasize studies on environmental remediation and on nonpolluting materials and processes, according to AFOSR's Charles Yee.

Yee, polymer chemistry program director in the Chemistry & Materials Science Directorate's chemistry division, says the environmental emphasis has necessitated cutbacks in other areas. For instance, the electrochemistry program will be eliminated entirely under AFSOR's proposed 1995 budget.

The Office of Naval Research (ONR) is undergoing a major reorganization to add technology to its mission, says Harold E. Guard, who manages programs in inorganic and organic chemistry there. "ONR used to be the Navy's office for the support of basic research through grants and contracts and the Naval Research Laboratory," he says. "There was a separate office for technology development. Now we are combined in one office meant to integrate science and technology."

Guard says ONR is essentially in chaos as it plans new directions for its technical programs. "My gut feeling is that we are under incredible pressure to move more to applied research," he says.

Such a focus on the eventual applications of research has been the norm at the Army Research Office, according to Robert W. Shaw, who heads ARO's chemical kinetics program. He says he expects the Army to keep funding for basic research stable, even while it is cutting back in other areas.

"All along, we have had to justify what we are doing in terms of its eventual benefits," Shaw says. "But we will be making more of an effort to communicate what we do to Army scientists and engineers who are our ultimate customers."

Continued on page 28

Energy research budgets continue to slip

$ Millions	1995[a]	1994[a]	1993[b]	% change 1994–95
ENERGY R&D	**$5,455.3**	**$5,734.9**	**$4,987.3**	**–5%**
General science & research	**1,113.1**	**1,615.1**	**1,406.3**	**–32**
High-energy physics	621.9	617.5	587.6	1
Nuclear physics	300.8	348.6	297.6	–14
Superconducting Super Collider	180.0	640.0	512.9	–72
General science direction	10.4	9.0	8.2	10
Supporting research & technical analysis	**910.3**	**934.9**	**883.8**	**–25**
Environmental restoration & waste management	**744.0**	**709.1**	**673.1**	**5**
Conservation	**610.8**	**414.6**	**300.2**	**47**
Fossil	**485.8**	**481.6**	**441.7**	**1**
Biological, environmental	**434.8**	**416.4**	**334.0**	**4**
Solar	**392.7**	**340.8**	**239.8**	**15**
Fusion	**372.6**	**342.9**	**317.9**	**9**
Nuclear fission	**231.9**	**319.7**	**239.8**	**–28**
Environmental health	**149.3**	**159.8**	**150.7**	**–7**
DEFENSE R&D	**1,187.8**	**1,266.5**	**1,446.4**	**–6**
TOTAL	**$6,633.1**	**$7,001.1**	**$6,433.7**	**–5%**

Note: Obligations **a** Estimate **b** Actual **Source:** Office of Management & Budget

NIST is major beneficiary of budget's technology emphasis

$ Millions	1995[a]	1994[a]	1993[b]	% change 1994–95
Industrial technology services	**$517.3**	**$287.4**	**$ 75.2**	**80%**
Advanced technology program	449.8	247.6	61.0	82
Technology transfer & outreach	67.5	39.8	14.2	70
Measurement & engineering research & standards	**303.9**	**224.8**	**182.0**	**35**
Computer systems	63.2	28.0	12.1	126
Materials science & engineering	60.2	45.0	37.3	34
Electronics & electrical engineering	30.0	29.8	24.8	1
Chemical science & technology	30.0	22.4	19.8	34
Manufacturing engineering	29.5	13.4	10.0	120
Research support activities	28.2	27.6	24.3	2
Physics	27.7	27.2	25.7	2
Technology assistance	14.5	11.1	9.5	31
Building & fire research	13.3	13.2	11.8	1
Applied mathematics & scientific computing	7.3	7.1	6.7	3
Research facilities	**100.0**	**61.7**	**102.0**	**62**
TOTAL	**$921.2**	**$573.9**	**$359.2**	**61%**

Note: Obligations **a** Estimate **b** Actual **Source:** Office of Management & Budget

Defense R&D is up 4% after 1994 dip

$ Millions	1995^a	1994^a	1993^b	% change 1994–95
Operational systems development	$10.869	$11.474	$10.586	–5%
Engineering & manufacturing development	8.916	7.441	8.487	20
Advanced development	5.117	6.115	6.282	–16
Demonstration & validation	3.771	2.698	4.212	40
R&D, test & evaluation management support	3.343	3.218	3.398	4
Exploratory development	2.984	2.743	3.549	9
Basic research	1.225	1.205	1.314	2
TOTAL	$36.225	$34.894	$37.828	4%

Note: Obligations **a** Estimate **b** Actual **Source:** Department of Defense

Environmental Protection Agency. During the first two decades of its existence, EPA spent most of its R&D budget on finding solutions to problems in specific media, such as air or water. In 1993, that emphasis began to change, and now in fiscal 1995, multimedia research is slated to claim nearly half the R&D budget. It also will receive the greatest increase, 29% over appropriations for 1994, to $272 million. A large part of this funding, $80 million, will go to the President's Environmental Technology Initiative, which provides federal assistance to private-sector development of innovative environmental technologies.

The National Human Exposure Assessment Survey, which measures toxic substances accumulated in human tissue, and the interagency research program of the National Science & Technology Council, which includes advanced manufacturing and high-performance computing, will also receive higher funding than in 1994. The U.S.-Mexico Border Project, a new program established under the North American Free Trade Agreement, will focus on environmental and exposure monitoring of populations that are subject to the greatest potential health risk from pollutants near the border.

Research on issues involved in implementing the Clean Air Act accounts for the second largest portion of EPA's 1995 R&D budget, about $116 million, a 9% decrease from 1994. Included in this figure are resources to study global climate change, stratospheric ozone depletion, health effects of air toxics, motor vehicle pollution, and indoor air pollution. Acid deposition monitoring will be performed under a different program, the Ecological Monitoring & Assessment Program. The remainder of the acid rain research program will be eliminated. Global climate change research will focus on assessment and mitigation of activities that increase the atmospheric levels of greenhouse gases.

Research related to Superfund will also receive less funding than in 1994, about $61 million, a decrease of 4%. Under this program, EPA will focus on watersheds and ecological risk assessment associated with Superfund sites. Groundwater research under Superfund will be directed toward means of removing non-water-soluble liquids from underground soil and fractured rock.

Construction cuts hurt USDA research

$ Millions	1995^a	1994^a	1993^b	% change 1994–95
Federal agricultural research programs	$ 708.6	$ 691.6	$ 668.0	2%
Partnership education programs	432.7	436.2	427.2	–1
Partnership research & academic programs	421.4	456.6	433.0	–8
Research facility construction	25.7	89.6	86.6	–71
National Agricultural Library	19.7	18.3	17.7	8
TOTAL	$1,608.1	$1,692.3	$1,692.5	–5%

Note: Obligations **a** Estimate **b** Actual **Source:** Department of Agriculture

At EPA, only multimedia and pesticide research post gains

$ Millions	1995^a	1994^a	1993^b	% change 1994–95
Multimedia	$272.0	$211.5	$164.1	29%
Air	116.3	127.7	127.8	–9
Superfund	61.4	63.7	64.8	–4%
Hazardous waste	28.6	32.0	40.5	–11
Water quality	25.2	29.3	29.8	–14
Toxic substances	23.0	25.2	24.7	–9%
Drinking water	18.8	19.5	19.3	–4
Pesticides	15.6	14.3	14.3	9
Management & support	6.7	6.5	5.9	3
Oil spills	2.1	2.1	na	0
Leaking underground storage tanks	0.8	0.8	0.7	0
TOTAL	$570.5	$532.6	$491.9	7%

Note: Obligations **a** Estimate **b** Actual **na** = not available **Source:** Environmental Protection Agency

Efforts aimed at protecting ecosystems, an integral part of many different R&D programs, also will receive increased funding. These efforts include environmental monitoring and risk assessment.

In nearly every R&D program, some of the research that has been performed by contractors over the past few years will be done by EPA staff in fiscal year 1995. However, some of EPA's in-house research efforts are also being cut back. For example, the Arctic research program that is run out of the EPA lab in Corvallis, Ore., is being almost totally shut down, and the lab's ecotoxicology program is being eliminated. Staffers who worked on this program will now be taking an ecosystem rather than a toxicological approach to environmental problems in the Pacific Northwest.

Agriculture. The budget proposal lays out major changes for agricultural research. The Clinton Administration wants to combine all of the Department of Agriculture's several research agencies into one entity.

NASA's overall budget is down, but support for R&D increases a little

$ Millions	1995[a]	1994[a]	1993[b]	% change 1994–95
Science, aeronautics & technology	**$ 5,901**	**$ 5,847**	**na**	**1%**
Space science	1,766	1,722	$ 1,563	3
Mission to Planet Earth	1,238	1,024	1,132	21
Aeronautical research & technology	899	1,102	858	–18
Advanced concepts & technology	608	495	na	23
Missions communication services	481	589	na	–18
Life & microgravity science & applications	471	515	na	–9
Launch services	341	314	na	9
Academic programs	97	86	79	13
Human space flight	**5,720**	**6,070**	**na**	**–6**
Space shuttle	3,324	3,549	na	–6
Space station	1,890	1,937	2,051	–2
Payload & utilization operations	356	413	na	–14
U.S.-Russian cooperation	150	171	na	–12
Mission support	**2,663**	**2,619**	**na**	**2**
Inspector General	**16**	**15**	**15**	**7**
TOTAL	**$14,300**	**$14,551**	**$14,294**	**–2%**

Note: Because of major restructuring in the National Aeronautics & Space Administration's budget accounts, many line items for fiscal 1993 are not available and those that are may not be entirely comparable with fiscal 1994 and 1995. **a** Estimate. **b** Actual. **na** = not available. **Source:** Office of Management & Budget

Under the plan, the existing Agricultural Research Service, Cooperative State Research Service, Extension Service, and National Agricultural Library will become the Agricultural Research & Education Service. According to USDA, this change would lead to improved coordination of intramural and extramural research programs and enhance delivery of new technology to the states.

But the reorganization doesn't mean more money. Overall, R&D funding at agriculture is essentially flat. Small gains in a variety of areas are outweighed by a 71% drop to $25.7 million in funding for building and facilities construction. Facilities funding under the Partnership Research & Academic Program (equivalent to the old Cooperative State Research Service) falls from $56.9 million in fiscal 1994 to zero next year. The Administration also plans a $7 million cut in construction funds for federal agricultural labs, from $32.7 million in fiscal 1994. This 21% cut comes despite admissions that major federal research facilities are functionally obsolete and in need of major modernization.

However, the budget does call for an increase of $17.8 million to $130 million for the National Research Initiative, which funds the only peer-reviewed grants USDA gives out. Funds for other parts of the program, which funds research in cooperation with state experimental stations and institutions, are frozen in the budget. For example, funds for the support of the traditionally black colleges under the 1890 Colleges and Tuskegee Formula, would total $28.2 million in fiscal 1995, the same as this year.

And a budget drop of $43.2 million is requested in the special research grant category, which funds researchers at many institutions. The Administration says it has cut out a number of Congressionally earmarked projects in this category and is seeking just $29.7 million in new funding.

For Federal Agricultural Research Programs (the old Agricultural Research Service), funding would rise 2% to $709 million. Major increases occur in the area of commodity conversion and delivery, which focuses on food safety concerns. This program is slated to receive $157 million in fiscal 1995, up $18.4 million. A proposed $10 million increase would fund research on alternatives to methyl bromide use in soil fumigation and quarantine treatments. Another high-priority research area is the reduction of pathogens in meat and poultry products.

National Aeronautics & Space Administration. This winter, NASA has been celebrating the triumph of its astronauts successfully correcting the Hubble Space Telescope's myopic vision. But the 1995 budget request for the agency is more in line with the unnerving string of failures that the agency had been experiencing: The President has proposed cutting NASA's budget 2% to $14.3 billion.

"This is not the usual good news-bad news budget for NASA," says Rep. Brown. "It's a case of bad news-worse news. The [proposed] budget is too low to support the vigorous space program envisioned by the Administration and by NASA."

Budgets for both the space shuttle and the space station, contained in the human space flight category, would be cut relative to this year. The same category would provide $150 million for collaborative projects with Russia. The funds would go, in part, to payments on a four-year contract with the Russian Space Agency for NASA's lease of the Russian *Mir* space station.

One of the few NASA programs to receive an increase would be Mission to Planet Earth, up 21% to $1.2 billion. The program is the centerpiece of the federal interagency global-change research program. Mission to Planet Earth employs satellite, aircraft, and ground-based instruments to observe and monitor large-scale environmental processes. The goal of the program is to provide policymakers the data they need to deal with global issues such as climate change.

More than one third of Mission to Planet Earth's 1995 funding, $455 million, would go to the Earth Observing System (EOS). EOS consists of a series of satellites, scheduled to begin launching in 1998, that will monitor many processes on Earth simultaneously. The budget also contains funds for smaller satellites called Earth Probes that will study tropical rainfall, ocean winds, and global ozone.

Funding for NASA's aeronautical research and technology programs would drop 18% overall in fiscal 1995 to $899 million. But the high-speed aircraft research program, which NASA describes as its highest priority research effort, would increase 12% to $221 million. The program's goal is to develop an economically viable, environmentally safe supersonic aircraft. The 1995 budget would continue funding for atmospheric chemists' ongoing assessment of the effects of the proposed planes' exhaust on the ozone layer.

As Brown cautions in his committee's analysis of the overall R&D budget, the President's budget request does not often translate into appropriated dollars. Almost all of the final research appropriations came in below requested funding levels in fiscal 1994. According to Brown, the same thing is likely to happen again this year. ☐

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CHEMICAL & ENGINEERING NEWS

C&EN

FEBRUARY 28, 1994

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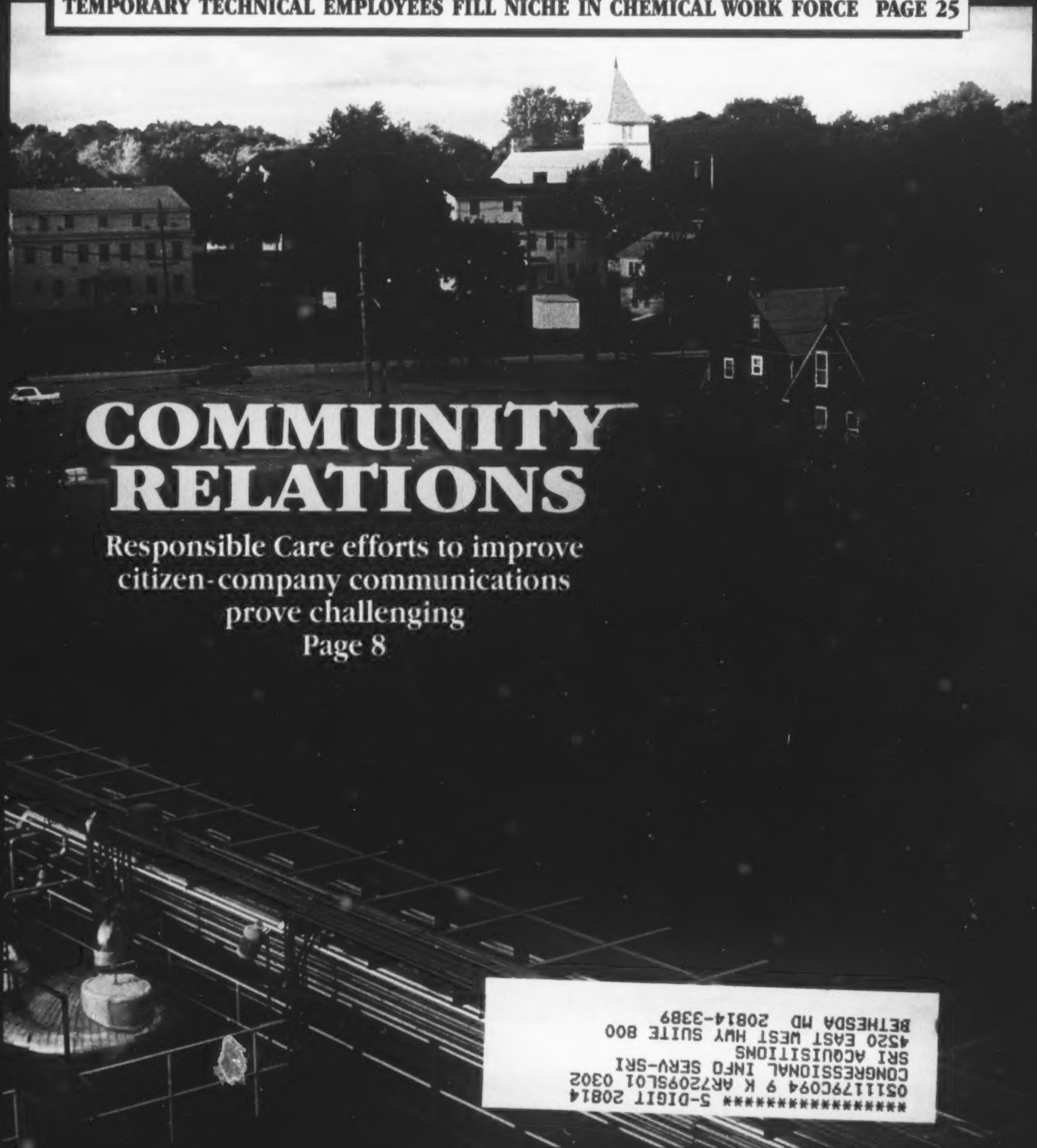

COMMUNITY RELATIONS

Responsible Care efforts to improve
citizen-company communications
prove challenging
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CHEMICAL & ENGINEERING NEWS

C&EN

FEBRUARY 28, 1994

NEWS OF THE WEEK

- NASA's space station program and Russia's role in the project are vehemently questioned at a House hearing. **Page 4**
- Ethyl Corp.'s spin-off of its subsidiary Albermarle Corp. is set—Ethyl Corp., with 53% of the current firm, will primarily manufacture petroleum additives; Albemarle will make specialty chemicals. **Page 5**
- The Supreme Court rejects an appeal by Vietnam veterans and their families to sue the firms that made defoliant agent orange. **Page 5**
- A number of chemists and chemical engineers are among the 79 new members and eight foreign associates elected to the National Academy of Engineering. **Page 6**
- Chemical industry representatives propose measures to improve the Administration's Superfund reform bill at a House subcommittee hearing. **Page 6**
- Hillary Rodham Clinton visits NIH, stresses Administration's support for basic research and lobbies for health care reform. **Page 7**
- The climate-change treaty signed at the 1992 Earth Summit needs to be strengthened, say delegates to an Intergovernmental Negotiating Committee meeting in Geneva. **Page 7**

COVER: Hoechst Celanese dyes facility at Coventry, R.I.

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BUSINESS

Many chemical companies are hiring temporary employees to meet technical labor needs, largely as a result of the continuing downsizing and cost cutting to improve profits. **Page 25**

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EPA is moving toward implementing various agency-formulated recommendations, as well as incorporating some EPA-specific White House suggestions, to eliminate waste and inefficiency. **Page 32**

Carnegie Commission report suggests reforms for Congress in handling scientific and technical issues—primarily by simplifying committee structures, relationships, and procedures. **Page 34**

SCIENCE/TECHNOLOGY

A solid-phase technique for synthesis of oligosaccharides and glycopeptides has been developed that may provide the basis for an automated synthesizer of these large molecules. **Page 37**

New information about the aromaticity of fullerenes comes from nuclear magnetic resonance studies of encaged helium-3 that indicated presence of ring currents. **Page 40**

EDUCATION

After being rocked by the Jan. 17 earthquake, California State University, Northridge, starts its spring semester—including chemistry labs—in temporary and borrowed facilities. **Page 44**

NEWS FOCUS

Efforts by the U.S. chemical industry to improve community relations, under the Responsible Care initiative, are encountering a variety of responses, from success to failure, but no one is yet giving up. Page 8

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LETTERS

Chemistry, chemical engineering

Councilor T. J. Logan's letter (C&EN, Jan. 10, page 3) makes an interesting point about higher initial pay for B.S. chemical engineers. Yet he seems to have overlooked Le Châtelier's principle—called the law of supply and demand in economics.

Raising the perceived value of the B.S. chemistry degree is laudable, but pointless. Better that we adjust to the demands of the market. First, produce fewer of the less valuable product (B.S. chemistry degrees). Second, produce more of the valuable product (B.S. chemical engineering degrees). Third, convert some of the less valuable product into the more valuable product. For example, chemistry departments should develop one- or two-year postgraduate chemical engineering programs.

I would be quite happy if the marketplace conformed to my preconceived notions of the great value of a good solid chemistry major; sadly, the marketplace is not constrained to follow my notions.

Charles R. Bennett
ACS Orange County Section
Fullerton, Calif.

Fred Tausch Jr., argues (C&EN, Jan. 31, page 5) that an increase in the number of high-paying jobs for chemists will follow from a decrease in the restrictiveness of environmental laws. To the contrary, I believe that the greater the challenges presented by tougher environmental regulations, the greater the demand for clever chemists who can forge new reaction pathways with higher yields and fewer unrecyclable toxic by-products. The solution to the problem lies elsewhere.

In my opinion, the paramount cause of the underemployment and undercompensation of chemists is the absence of professional-chemist political clout from which economic clout follows. Under the current system, academia dictates supply and the chemical industry dictates demand and compensation, while practicing chemists observe from the sidelines. Public education will help put chemical risks into proper perspective while enhancing the image of the practicing chemist, but education is not enough. I propose a political solution that uses, rather than fights, the public's legitimate concerns about chemical safety issues to provide practicing chemists with the economic clout they seek.

First, ACS should develop and administer a set of certification exams for the professional chemist (P.C.) and publish standards of professional conduct and a code of professional ethics for chemists. These would include the requirement that all commercial chemical syntheses and associated materials management processes and procedures be certified by a chemist P.C., as meeting standards of quality and occupational, consumer, and environmental safety established by the profession.

Second, ACS should draft and press for the adoption of ordinances at the local level and legislation at the state and federal levels that require that a chemist P.C., and a chemical engineer P.E., certify that chemical syntheses and associated materials management processes and procedures meet the standards of practice of their respective professions. Licensing requirements should be mandated for chemists and chemical engineers who develop syntheses for listed hazardous substances or who develop recycling or disposal processes or procedures for their wastes. ACS should target the Toxic Substances Control Act; the Federal Insecticide, Fungicide & Rodenticide Act; the Hazardous & Solid Waste Act; the Superfund Amendment & Reauthorization Act; and the state equivalents of these initiatives.

If the ordinance and legislative initiatives are successful, without both chemist P.C. and chemical engineer P.E. certification, a chemical manufacturer would not be able to obtain the insurance and local, state, and federal permits required to manufacture, formulate, store, use, recycle, or dispose of any chemical.

Under such new standards of practice and ordinance or statutory requirements, a chemical engineer P.E. alone could not ethically or lawfully make such certifications. In this way, legitimate concerns about the hazards of chemicals would work to the advantage of practicing chemists, precluding the substitution of a chemical engineer's judgment where that of a chemist is required. This set of initiatives would provide chemists with political clout via economic leverage and economic clout via political leverage. Salaries for a chemist P.C. should rise to the level of the chemical engineer P.E. in as little as one permit reissuance or insurance adjustment cycle.

Of course, college curricula would also have to be modified to reflect these new requirements. During the changeover period, ACS could offer certified short courses to fill in the knowledge gaps. This would also serve the need of practicing chemists who wish to seek P.C. certification.

If chemists do not organize and act to protect the public from the mismanage-

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Temporary Employees Fill Niches in Chemical R&D Work Force

■ ***Downsizings and cost cutting prompt chemical firms to go outside the company to meet their technical labor needs***

Ann M. Thayer,
C&EN Northeast News Bureau

The chemical industry has been showing signs of recovery. But recovery has not come without sacrifices. Companies have been reducing expenses, reorganizing operations, and cutting work forces to improve earnings performance. According to the U.S. Department of Labor, chemical employment decreased in 1993 by 16,000 jobs, to 1.06 million, largely the result of downsizings at companies. And this downsizing has hit R&D as well as other segments of the industry.

In light of a bleak outlook for technical jobs (C&EN, Oct. 25, 1993, page 42), many in the industry believe that the days of being assured of indefinite regular—what was once called permanent—employment may be gone. At many companies, contract and temporary employees are the first to be cut. Other firms, having reached what they are calling core staffing levels, are trying to increase efficiency and productivity and may turn to temporary help to handle continuing workloads and control personnel costs.

The overall temporary employment market has been growing dramatically, according to the Washington, D.C.-based Economic Policy Institute (EPI), expanding 36% between March 1991 and July 1993 and contributing nearly 28% of the 1.9 million new jobs created during that period. The chemical industry has long used highly skilled contract employees, specifically engineers, in plant construction and expansions, process development, and environmental projects. Now, however, there is a growing use of temporary employees, many at the professional level, in R&D and other technical areas. And employment firms are specializing in providing temporary employees with technical backgrounds.

"The name of the game is value-added services," says John Skaff, senior vice president of MTI, a St. Albans, W.Va.-based firm that supplies contract engineers and temporary workers to the concentrated chemical industry in the surrounding Kanawha Valley. Contract companies are being asked to supply not only skilled people, he explains, but often also services or equipment that companies do not have or do not want to purchase themselves.

For example, a company may want a temporary engineer familiar with computer-aided design to arrive with a computer system in hand. "MTI can buy a computer workstation faster and less expensively than a client who has to go through internal requisitioning," explains Skaff. "And, if we have a computer in stock, we can have it and a person there the next day to do the job and then leave when it's done." At the same time, he says, chemical companies are "outsourcing" more of their work because they no longer have the internal resources and are depending on contract firms to take greater leadership roles in projects.

The market for contract engineers has been very good from two perspectives, says Skaff. Not only are companies looking for contractors to fill project needs, but the contract engineering firms themselves have been "blessed" with a large number of early retirees from chemical companies. Contract firms are now competing to attract these individuals.

Although the use of temporary employees by chemical companies is growing, companies such as Dow Chemical and Union Carbide do not foresee significant in-

Lab Support's Steven Messick (above), Woodrow Smith fill in on a variety of technical jobs.

Temporary R&D employees in unique roles at DuPont and Henkel

Exploratory R&D for new business development can be a very uncertain area in which to commit resources. At the same time, it can have special needs and require expertise, especially in emerging technologies. And such technologies are not always part of a company's core scientific base. To keep the risks down, the costs low, the pace brisk, and the level of flexibility high, Vinay Chowdhry in DuPont's Division of Corporate New Business Development, has put together an R&D team that relies heavily on both temporary employees and a group of DuPont researchers drawn from throughout the company.

"Our role is to create major new businesses as well as to experiment with new ways of developing businesses as market conditions change," says Chowdhry, who is general manager for the food quality management systems business initiative. The food quality systems team is developing instrumentation and testing that are expected to improve the analysis of the quality and safety of products and processes in the food industry. It also accesses technology through relationships with outside companies and other organizations.

"The primary driver for bringing in temporary workers was to ensure that we could get up to speed real fast," says Chowdhry. "We can bring in people with backgrounds we do not have when we need them, but also on short notice change the pool of people working on the project as it evolves. And, quite honestly, keep the costs way down. It's been extremely successful."

Temporary employee Willie Dorine Hudson on DuPont team tests and evaluates instrumentation.

At times, the number of contract or temporary workers has been one third or more of the team. Over the five-year life of the project, Chowdhry estimates that more than 100 temporary workers have been employed. By working closely with temporary help companies, and also by screening temporary as well as DuPont employees very carefully to find good matches, Chowdhry says that there has been no difficulty in finding high-quality people on very short notice. Temporary employees on the team have ranged from the bachelor's to doctorate level at all stages of their careers and in the areas of chemistry, biology, mathematics, various engineering disciplines, and computer programming.

DuPont has worked hard in running the team to ensure that no distinction is made between temporary and permanent DuPont employees, says Chowdhry. But, so not to mislead people, the

creases in their numbers over the next few years. Chemical companies are somewhat hesitant to talk about their use of temporary or contract employees, partly because many of them have gone or are going through downsizings. They are sensitive both to the impact these cutbacks will have on employee morale and to employee reaction to seeing the work of displaced employees being done by temporary ones.

A spokesman for Dow Chemical says the company uses a small percentage of contract employees at all levels in R&D and engineering work for very specific, well-outlined jobs. The situations for which outside employees are used generally fall into two categories: when Dow has the need for expertise it does not have internally, or when the work is short term.

Donald Gatewood, manager for recruiting and university relations at Union Carbide, says Carbide's use of temporary employees probably is more prevalent in engineering where the workloads are variable. Temporary or contract employees add flexibility in satisfying project needs and peak workloads. When a project is completed, the number of engineers can be reduced on the contractor side of the project without adversely affecting permanent employees.

In addition to meeting peak or short-term project demands, temporary help provides a way to get around hiring freezes, to cover vacancies when employees are on leave, or to fill high-turnover positions. Repeated hirings and firings, or the alternative of keeping employees on the payroll during lulls, can therefore be avoided. Companies wanting temporary employees generally contract with a company that supplies workers with the desired skills on an "as needed" basis. These workers are then paid on an "as used" basis at an agreed upon rate.

Since temporary employees are not their employees, client companies do not have the same responsibilities that they have for their own employees. Thus, many users of temporaries tout the potential cost savings from avoiding long-term payroll, retirement, and severance commitments, as well as rising benefit and other personnel costs. Temporary help companies, as the employers, usually fall under federal labor laws and must provide benefits such as health insurance, worker's compensation, and unemployment insurance.

To receive benefits and vacation leave, employees typically must meet eligibility requirements such as working a minimum number of hours per year. In some instances, temporary help companies offer retirement and savings plans to longer term employees as a means to attract or retain them. These overhead costs, as well as employee wages, are recovered in the billing rate charged to clients. Independent contractors or temporaries who work through third-party placement agencies must obtain their own insurance.

The temporary employment industry is extremely fluid, with a turnover rate of 600% or more, explains Bruce Steinberg, a spokesman for the National Association of Temporary Services (NATS), an Alexandria, Va.-based trade association. Because of the nature of the industry, many temporary workers don't work long enough for one temporary help firm or do not choose to participate in long-term benefits, he says, especially retirement.

But opponents of temporary help, such as EPI and the San Francisco-based group New Ways To Work, say that contingent workers—including part time and tempocompany has made clear that working on the team is not a stepping stone to permanent employment with DuPont. And there have been no exceptions. Chowdhry believes that open attitudes and frank discussions have contributed to team members putting aside concerns about employee standing and instead have led to a strong sense of focus, intellectual excitement, and, in turn, loyalty to the project itself.

As a member of the DuPont team since June, Jay Bass says his experience as a contractor has been unique. What is unusual, he says, are both the large number of temporary employees and the equitable way in which they are treated as fellow collaborative scientists. Bass describes himself as a Ph.D. bioengineer—a multidisciplinary degree involving the development of instrumentation for life science applications.

Bass worked as a contractor for a few years during graduate school and has continued to do so since recently finishing his degree. Incorporated as an independent contractor, he must not only find his own assignments and benefits, but also must negotiate his contract. With the uncertain market for permanent jobs, Bass seems content to work independently, viewing it as a way to take advantage of new opportunities while earning a competitive salary.

Exceptions to the usual type of temporary employee on the DuPont team are those fresh out of undergraduate or graduate school. Chowdhry says he is looking for individuals with very specific skills and some experience in the workplace. In contrast, Judith C. Giordan, vice president for R&D at Henkel, uses many recent graduates and undergraduates, as well as higher level people, as an integral part of that company's technical support staff.

Henkel does not employ any permanent employees at the technician level, she explains, which means that Ph.D. scientists play a greater hands-on role in research and that temporary employees are not replacing permanent ones. To fill short-term technical support needs with qualified workers, the company usually hires temporary employees at the bachelor's and master's degree levels. This approach has been very successful—Giordan cites some instances of young temporary employees bringing recently learned up-to-date expertise or skills—and has become part of the company's R&D culture.

Overall, Giordan is extremely positive about the merits of using temporary employees and specifically sees the use of younger workers as a great opportunity for the temporary employees themselves. "Many times, because the job market is tight, they can't get a job if they don't have experience," she says. "A lot of temps have gone on to permanent jobs using [working at Henkel] as their experience base ... [while] it gives the company the highly skilled temporary work force it needs."

Chowdhry and Giordan agree that a major concern of companies that use temporary employees is the disclosure of proprietary information, and both say employees are asked to sign confidentiality agreements. But, if necessary, says Giordan, it is possible to define the nature of the work very clearly so as to avoid an employee's having to know too much—for example, why data are needed or what the market end uses are. The company "is trying to protect everyone," says Giordan. "It wants to make sure that temporary employees are not put under a liability situation if they were to get a full-time job in a competitive area."

raries—do not have access to training and advancement opportunities and, more often than not, lack the benefits and protections afforded other workers. Specifically, these groups take issue with inconsistent state eligibility requirements for unemployment insurance, qualifications for pension coverage, job security and safety, and access to health care coverage. The Department of Labor has set up a special task force to study the contingent work force. And a broad range of issues related to contingent workers is being examined by Sen. Howard M. Metzenbaum (D.-Ohio), who heads the Senate Labor & Human Resources Subcommittee on Labor.

A significant amount of concern also centers on companies believed to be using contingent workers not to supplement their work force, but rather as low-pay, low-cost replacements for large numbers of full-time employees. "Companies have always used contingent workers to supplement full-time workers to meet additional demand," says Greg Watchman, an aide in Sen. Metzenbaum's office, "but now they are being used to replace full-time workers and eliminate full-time jobs." If the trend continues, he adds, some observers expect contingent workers to outnumber permanent employees by the end of the century.

But many connected with the temporary employee industry say that this is not what the industry strives to do or how it works. Replacing permanent employees "is not temporary help, it's cheating," says H. Tom Buelter, chairman, chief executive officer, and president of On Assignment, a Canoga Park, Calif.-based temporary help company. "Temporary help has become a management tool. It's about managing your ups and downs in the work force and labor market shifts.

"Companies already have made commitments to their work forces, but when there is extra work, then it is done by the professional temporary work force," he says. "The reason [temporary help companies] have not been affected and probably won't be affected by any recessions is because our people actually do work. Companies don't hire temporary employees and then not know what to do with them."

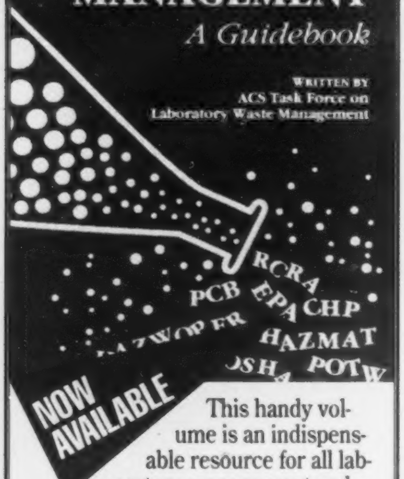
Temporary help, says NATS, can act as a flexible bridge to permanent employment by providing training and job experience in skills that are in demand; providing opportunities for workers to "showcase" their talents with a variety of potential employers; and providing relief from financial pressures while workers look for better job offers.

On Assignment's primary operating division, Lab Support, specializes in providing temporary technical employees—an area that it says is one of the fastest growing niches. On Assignment's revenues in 1993 grew 17%, to $38.1 million, and net income jumped 40%, to $2.5 million. The division has about 30 branch offices across the U.S. About 1,200 Lab Support employees are on assignment at any given time, with about 35% in R&D.

Lab Support was founded in 1985 by Bruce Culver and a fellow chemist, Raf Dahlquist. Culver, who remains a stockholder in the company, now operates Lab Staff, which supplies temporary technical employees in the U.K. and France. Many of Lab Staff's clients are U.S. companies with operations overseas, says Culver, and the needs are similar to those in the U.S. In the U.K., Lab Staff has four offices and employs about 400 temporary scientists on a given day. With two offices located near Paris, about 150 temporary staff are employed in France.

LABORATORY WASTE MANAGEMENT
A Guidebook

WRITTEN BY
ACS Task Force on
Laboratory Waste Management



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Clients of Lab Support and Lab Staff include many major companies in the chemical, petrochemical, environmental, biotechnology, pharmaceutical, food, and other industries. High-risk or high-liability positions, including many in medical areas, frequently are avoided by temporary technical help companies. Most assignments last for an average of about four months. The success of these two companies, says Culver and Buelter, stems from employees being selected, placed, and managed by a system of account managers. These account managers are themselves trained scientists with industrial experience who can work knowledgeably with client companies.

Both Lab Support's and Lab Staff's employees are chemists, biochemists, biologists, and microbiologists ranging from the master's degree level with upwards of eight years' experience to the bachelor's degree level with less than one year's experience to technicians with some chemistry or biology background. The typical employee is a young college graduate with anywhere from zero to six years of experience.

"The company is providing a great opportunity for the entry-level person," says Buelter. Young employees can get their feet in the door at major companies, gain valuable experience with different employers, obtain exposure to different kinds of work, and get paid for it. After building their résumés, even if they have to start in mundane positions, they can move on to better, permanent positions. Lab Support offers assistance to its employees in developing interviewing skills and in writing résumés.

A good example is Chris Runz, who received his undergraduate degree in biochemistry in spring 1993 and began working as a temporary employee while awaiting admission to medical school. He obtained a temporary position at Hoechst Celanese in late September 1993, having been placed by Lab Support only a week after applying. Runz views his temporary work experience very positively and is happy to have been able to find work in his undergraduate field. Admittedly, he says, the work is routine analytical work, but "at least I've been given the opportunity to work full time."

Many employers use the temporary work experience as a means to assess the skills and acceptability of new employees before hiring them for the long term. Less risk is involved in this approach be-

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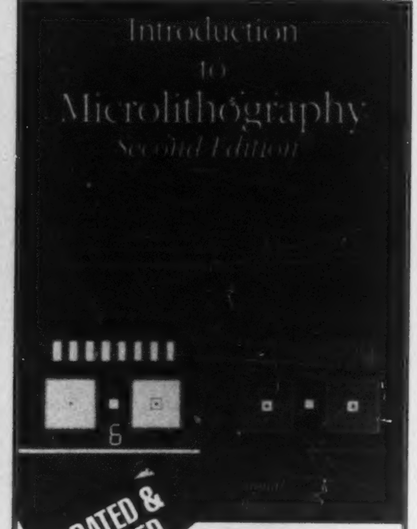

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cause, although companies still may be investing in training, they have not had to spend time recruiting nor have they made any long-term commitments. Depending on the length of an assignment or the amount of time since its completion, a client company may have to pay a fee to the temporary help company when hiring the temporary employee permanently.

Even though it means that they are losing employees, executives and managers at temporary help companies see the transitions to permanent employment as complimentary—reflecting on their ability to recruit, screen, and appropriately place quality employees. Buelter says about 20% of Lab Support's employees convert to regular full-time employment on their first assignment. Another 30% return for new assignments, and the remaining ones move on for whatever reasons. Skaff of MTI says that, with the downsizings and hiring freezes in the chemical industry, he recently has seen fewer transitions from temporary to permanent employment than in previous years.

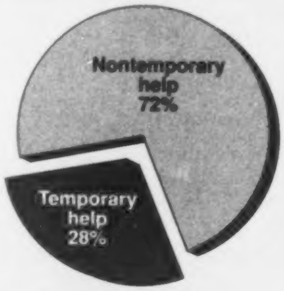
Executives at temporary employment companies say that their technical employees are paid competitive, or higher, hourly wages than comparable permanent employees. Client firms are said to be usually willing to pay the premium wage, and added overhead costs, for short-term hires.

In some instances, the higher pay helps offset lower benefits. For example, a day off for vacation or illness is often unpaid leave. In most cases, the higher pay helps to attract and retain good employees who might otherwise not be interested in temporary employment.

"Temporary work provides flexibility to both the employer and the employee," says Buelter. For many employees, at any level and any stage in their careers, temporary work serves as a buffer between jobs, or as a way to change jobs or find work after moving. Buelter says very few people are working on a temporary basis after two years, although some have become long-term employees of Lab Support.

Ida Ita, an analytical chemist with an M.S. degree, has worked twice for Lab Support—once in the late 1980s after being affected by downsizing in the pharmaceutical industry and again recently when the drug company she worked for moved her department out of state. "The world is constantly changing, and it doesn't look too good right now [for jobs]," she says. "I am hoping that something permanent will show up, but if not, I will continue working on a temporary basis."

Temporary help is about one fourth of new jobs



New jobs[a] = 1.9 million

[a] All U.S. jobs created between March 1991 and July 1993. **Source:** Economic Policy Institute analysis of Bureau of Labor Statistics data

Ita was placed at Ortho Biotech in Raritan, N.J., by Lab Support in May 1993. Currently, three temporary and two permanent employees work in her department. She says there is no difference in how temporary employees are treated in terms of their training, safety, or involvement in company activities. "I think [other employees] have to accept you," says Ita. "Everyone has work to do and, if you are capable, you do it and you are paid accordingly."

Employees who have the most difficult time finding temporary work are Ph.D.s, says Buelter, because companies are not interested in hiring them for temporary assignments. Although many Ph.D.s come to Lab Support looking for work, he says, the company does not hire them because they are too difficult to place. However, Culver says that Lab Staff is able to find temporary positions for Ph.D.s.

"People lambaste the whole concept of temporaries, thinking that the idea of providing temporary scientists is undermining the full-time employment of scientists," says Culver. "This isn't the 1960s anymore when people could go to work for a big company and plan to retire from the same company. . . . The world is more dynamic and so careers change as well.

"In our education of scientists, we just have to be a little bit more street-smart and a little bit more flexible—and [we need to] have a little broader perspective of where we stand in relation to our careers." ☐

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SCIENCE IN AMERICAN LIFE

ACS-sponsored exhibit set to open at Smithsonian
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MARCH 7, 1994

NEWS OF THE WEEK

- EPA has issued a final rule to cut toxic air emissions from chemical plants almost 90% from 1990 levels. **Page 4**
- Scientists at Oregon State University have found strong evidence for a biological effect of ozone depletion—a drop in frog and toad populations stemming from UV radiation killing their eggs. **Page 5**
- Biomass burning is shown to be a significant source of methyl bromide emissions, raising questions about effectiveness of scheduled restrictions on the synthetic compound, a fumigant, in halting ozone depletion. **Page 5**
- White House urges Congress to ban most exports of hazardous wastes to countries outside North America, implementing an international agreement, the Basel Convention. **Page 6**
- Plans for commercialization are being prepared for a new nonstick coating discovered by Dow Chemical and licensed to 3M for development and marketing. **Page 6**
- New industry-government partnership agreement to spur advances in critical semiconductor technologies has been unveiled by the Clinton Administration. **Page 7**

COVER: Smithsonian's logo for "Science in American Life" exhibit

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BUSINESS

Hercules' Thomas Gossage has reinvigorated the old-line specialty chemicals maker, largely by selling nonperforming businesses, cutting capital expenditures, and improving operating profits. **Page 11**

DuPont is reorganizing its R&D program, says new senior vice president for R&D Joseph Miller, with changes in management structure, leadership teams, and marketing. **Page 13**

Business Insights: Clinton Administration's recently released economic forecast sees an upturn in key sectors of particular importance to the chemical industry. **Page 14**

GOVERNMENT

White House has finally moved to support reform of OSHA; proposed legislation seeks changes in areas such as standards-setting, enforcement, and employer-employee relationships. **Page 18**

NSF's latest "Science and Engineering Indicators," a compendium of U.S. science capabilities, points up growing international interaction in research, changes in R&D spending. **Page 20**

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Feasibility of deliberately engineering Earth's climate—and the social, economic, political, and ethical issues raised by such actions—are examined by researchers and other experts. **Page 26**

Mechanism for the formation of fullerenes from large planar carbon rings, involving a spiraling carbon-chain intermediate, is proposed by a research group at Northwestern University. **Page 27**

PERKIN MEDAL

American Cyanamid's Marinus Los receives the 1994 Perkin Medal for his achievements in applied chemistry, especially his invention of environmentally friendly imidazolinone herbicides. **Page 29**

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"Science in American Life," a permanent exhibit sponsored by ACS at the Smithsonian's National Museum of American History, scheduled to open in April, allows visitors to explore the dynamic, often controversial, connections between science and society. Page 30

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LETTERS

Response to Luberoff

My friend Ben Luberoff (C&EN, Jan. 31, page 4) said, in essence, that universities are educating chemists to be watchers and that he would like them to be trained to be doers.

That's a common sort of view, Ben, and a dangerous one if we want America to be strong and our industry to prosper. When faced with a practical problem, many of us like to say, "Let's just do it, not take time to study it." That popular choice is a good one if the technologies to be used and the situations to which they are to be applied are thoroughly understood, in all their aspects. But if they are not, a fiasco may result. A little fiasco may do no more than ruin a career, but a big one may cost billions of dollars.

To a considerable extent, Ben, you are asking that the universities train, rather than educate, chemists. I have written before about the importance of education [*J. Chem. Educ.*, **65**, 744 (1988)], and urge you to read what I wrote. I do not deny the importance of good training for technicians, but urge that it not be confused with the mind-broadening experience of true education.

Your letter is also disturbing in that it tends to challenge the validity of fundamental research, that is, research directed toward the recognition of new principles. If we define research as search for knowledge, it spans activities ranging from looking up a physical constant in a handbook (admittedly a marginal case) through finding facts by diligent study in libraries or manuscript archives, and determination of new data by application of known principles, to efforts to discover principles previously unrecognized. You and I would agree that the last of these modes of research would seldom be the one to use for the quick solution of a practical problem. I am, however, alarmed that even the less adventuresome kinds of research that I mentioned are sometimes ignored by "practical" technologists.

It is said, in regard to financial investments, that high returns are associated with high risks. Much the same is true about research. Applied research gives a secure but modest return; it is a kind of insurance against disaster. Fundamental research directed at discovery of new principles is risky, and sometimes totally unfruitful, but when an important new principle is found, a great new industry may result. We need research of all kinds.

It is possible, Ben, that you were dismayed that some recent chemistry Ph.D. recipient was inept doing laboratory work that needed to be done. That can happen if the student's research adviser kept the student busy at a single sort of experimental activity, such as sitting at the console of an instrument, throughout the student's dissertation research. In such a case, the student has been denied the mind-broadening experience of dealing with a variety of methodologies, and might, in extreme cases, almost be said to have been trained as a technician.

Joseph F. Bunnett
University of California
Santa Cruz

Cooperation not confrontation

You are absolutely right (Editor's page, C&EN, Feb. 14, page 3). Resolving the chlorine debate—or any other public policy issue—requires the full cooperation of industry, government, and the public.

That's why we were cheered when then-President-elect Clinton promised a new era in regulatory policy-making, one that stressed cooperation—not confrontation—between industry and government.

We also agree that public policy should not be held hostage to any group's politics or ideology. Policy-making, should be open, inclusive, and grounded in the best scientific information available.

Yes, we do get frustrated when the process breaks down, but the Chemical Manufacturers Association is always ready and eager to work with the Environmental Protection Agency—or any other party—to create policies that, as you so elegantly wrote, "inspire public confidence."

Frederick L. Webber
President, Chemical Manufacturers Association
Washington, D.C.

Letters to the Editor

C&EN encourages readers to contribute to this letters section. However, please keep letters reasonably short—400 words or fewer. Because we receive a heavy volume of letters, persons writing letters are limited, as a general rule, to one letter within any given six-month period.

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standards on ergonomics, medical surveillance, exposure monitoring, and other specific issues.

The outlook for OSHA reform legislation this year is not good. The issue is an emotional one and highly partisan. It is not lost on legislators that the Clinton Administration waited more than a year before coming out in support of workplace safety changes, even though there had been several earlier opportunities. The obvious conclusion is that the Administration would like to see some reform in this area, particularly to please its friends in the organized labor community who were angered by Administration support of the North American Free Trade Agreement. Clinton, however, has not given OSHA top priority.

Any prospects of passing OSHA reform soon are dimmed by the pending retirements of those House leaders seeking health and safety changes. Both Education & Labor Committee chairman Ford and Labor Standards, Occupational Health & Safety Subcommittee chairman Rep. Austin J. Murphy (D.-Pa.) have announced they will leave Congress at the end of this session. Ford was the primary sponsor of OSHA legislation in the House for the past two sessions. At this time, there does not seem to be any member of Congress poised to take up the fight.

David Hanson

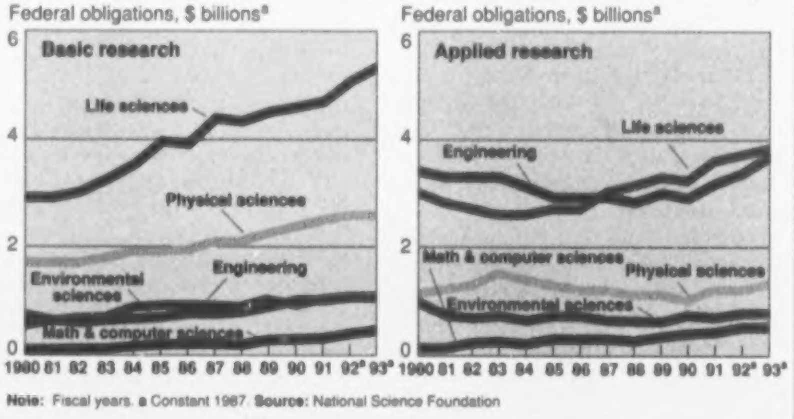
NSF report tallies current U.S. science capabilities

Want to know how well American kids rate compared with other schoolchildren around the world in science and math skills? Or what the public thinks of the impact of science and technology on their lives? Or how well the U.S. is competing with other leading countries in the so-called critical technologies? Or the impact of the end of the Cold War on the funding of research in industry and academia?

If so, there's a one-stop way of finding out—by picking up a copy of the 3½ lb, browser-friendly "Science and Engineering Indicators" for 1993. Every two years, the National Science Foundation's (NSF) board of directors, the National Science Board (NSB), issues this hefty compendium of facts about science and technology. The U.S. was the first country to issue such a volume (beginning in 1972 as merely "Science Indicators") and NSF's science resources studies division, which does all the compiling, has pretty much set the world standard for such efforts.

"Indicators," always a science and technology policy event, is customarily accompanied by a policy statement from the board itself. But the board usually uses language that critics find rather homogenized for a body that by charter is expected to set a leading, and critical, tone for national science policy. This time, however, the board summoned uncharacteristic verve in its policy recommendations. Its 23 members are clearly concerned that academic-business collaborations have opened the door to conflict of interest and intellectual property issues. The board calls for development of ethical guidelines governing those relationships. It also calls for a "fresh and vigorous national vision for public support of science and technology." But it disappoints in failing to suggest a way to conjure that vision, or who is to venture the effort.

Life sciences outpaces other sciences in research funding



Note: Fiscal years. a Constant 1987. **Source:** National Science Foundation

The 1993 edition, sporting a psychedelic cover of four vitamin crystal photomicrographs, is the biggest yet, at 518 pages. Its chapters cover elementary and secondary science and mathematics education; higher education in science and engineering; the science and engineering work force; financial and institutional linkages in research and development; financial resources, personnel, and outputs of academic R&D; technology development and competitiveness; and public attitudes and understanding of science and technology.

Program director Jennifer Sue Bond wrote the opening overview chapter. She finds that scientific and technical "enterprise" is increasingly global in nature, and that international interaction is increasing. For example, overseas research financed by U.S. companies has grown five times faster than that performed domestically. Foreign firms, for their part, are increasing the amount of R&D they do in the U.S. "Indicators" says foreign R&D made up more than 10% of industry's total in the U.S., U.K., Canada, and France.

Another overall conclusion is that the U.S. continues to undergo changes in the composition of its R&D spending. The federal government supported only 42% of all R&D in 1993, down from 46% in the mid-1980s. Industry spends 52%, with states, universities, and nonprofit organizations making up the rest. Funding from this group has doubled from 3% to 6% since 1985, reflecting a trend toward diversifying sources of support.

The fabled individual investigator effort—fount of technical creativity in the U.S.—has not suffered as much as its advocates say it has. Individual investigators receive more than half of all academic research support, about the same as they always have. The rest, of course, goes to support team, interdisciplinary, and research center efforts.

"Indicators" says the universities are taking on more of the country's R&D—$20.6 billion in 1993—but the federal share has declined. It was 56% in 1993, compared with 68% in 1980. The insti-

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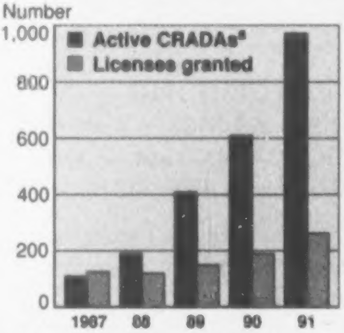
tutions themselves provided 20% last year and industry provided 7.3%. Strangely, the overview almost bends over backward to avoid even the suggestion of a plea for more support, or, at the opposite end, the possibility that academia may have overbuilt its research plant.

In the nearest thing to a statement reflecting the board's political agenda, "Indicators" says the importance of basic research to meeting strategic goals is "receiving increased national attention." Evidence for that is rather slim in "Indicators," since the definition of basic research has gotten looser and looser since the days when Ronald Reagan was President. In any case, the political trend today is toward immersing basic research within a strategic context, much as the NSF's old Research Applied to National Needs program tried to do up until 1980 when NSB, in a stroke that erased a vision, killed it.

However, the 1993 "Indicators" is not shy about using the term "investment"—the Clinton Administration euphemism for "spending," or "support." And it indicates that national goals are going to be the determining element in any further R&D growth. Interagency research initiatives in such areas as biotechnology, global-change research, and advanced materials and processing accounted, at $12.5 billion, for one sixth of 1994 federal R&D support. "And new federal strategic initiatives are being developed," Bond says.

One of those strategic areas—health—is the most robust R&D "investment" in the country, after defense, account-

Federal lab-industry R&D pacts near 1,000 in 1991



[a] Cooperative research and development agreements; include agreements entered into by National Aeronautics & Space Administration.
Source: Department of Commerce

Funds for dual-use technologies approaching $500 million

Program	Fiscal 1994 R&D funding for defense conversion ($ millions)
Manufacturing experts in the classroom	$ 5
Manufacturing engineering education	44
Defense advanced manufacturing technology partnerships	24
Defense dual-use critical technology partnerships	82
Commercial-military integration partnerships	42
Regional technology alliances assistance	91
Defense dual-use assistance extension	91
Manufacturing extension	82
TOTAL	**$461**

Source: Advanced Research Projects Agency

ing for 40% of federal basic research spending. However, most of the increases the health area has received have been going to AIDS research.

Overall, the downsizing of the Pentagon's budget has had the most drastic effect on national R&D. The figures, on the surface, paint a confusing picture of the implications of that downsizing for R&D because although R&D accounted for 10% of the defense budget in 1980, it rose to 14% in 1993, according to the report. At the same time, "preliminary data show that the number of R&D scientists engaged in defense-related work declined 6%, dropping from 730,000 in 1990 to 684,000 in 1992. In the aircraft and missiles industry, the decline has been 20%." "Indicators" says the situation will get worse through the nineties.

The Pentagon is trying to soften the impact of such cutbacks by supporting a program of "dual-use" technologies through its Technology Reinvestment Project. TRP, operated out of the Advanced Research Projects Agency, spent $461 million in fiscal 1994 to help high-tech companies switch to technologies that serve both the commercial and defense markets.

In the commercial field, cooperation and collaboration between universities and industry, and within industry, have been spreading wildly. About 1,000 university-industry research projects existed by 1991, 72% with federal funds. Academic and industrial researchers are jointly publishing more than ever. In 1991, 35% of all industrial papers were done in collaboration with academics, compared with 22% a decade earlier.

The section on international competitiveness in technology is perpetually interesting in a shifting landscape. The challenge for "Indicators" is always to remain current with—and even anticipate—shifts and to reckon whether data collected in 1992 appropriately serve the 1994 reader. "Indicators" was essentially completed during the last third of 1993, predominantly using 1992 data. In 1992, an election year, the decline in U.S. competitiveness was a strong concern in the country. Today, however, competitiveness news is dominated by stories about how well the U.S. has caught up with Japan in industry after industry, including autos. There is a new optimism in the air. Leadership in the hottest new set of technologies—those composing the electronic information superhighway—seems to belong to the U.S. But for how long?

"Indicators" believes that other nations are catching up with the U.S. in key high technologies such as communications equipment, computer/office equipment, and electrical machinery. Substantial trade surpluses remain in aircraft, pharmaceuticals, and scientific instruments. Looking further ahead, the report predicts that the impact on global economics by newly emerging countries in technology—Malaysia, India, China, and Indonesia—will be profound.

"Indicators" always devotes a chapter to public attitudes toward science and technology. Accounts of the public attitudes survey roll on, page after page, revealing that "70% of Americans continue to express the view that the benefits of scientific research exceed risks or harms associated with that work." In contrast, "Only 12% thought of themselves being well informed about issues involving new scientific discoveries."

Wil Lepkowski

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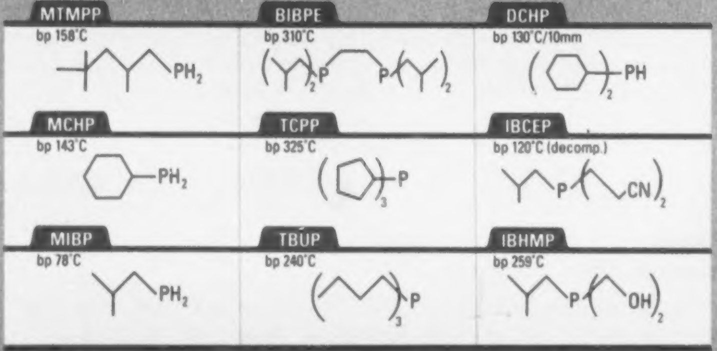

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CHEMICAL & ENGINEERING NEWS

C&EN

MARCH 14, 1994

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INSTRUMENTATION

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CHEMICAL & ENGINEERING NEWS

C&EN

MARCH 14, 1994

NEWS OF THE WEEK

- Study finds that investments and technology transfers by U.S. chemical firms in developing nations are deterred by weak intellectual property protection. **Page 6**
- At a Senate hearing, U.S. technology leaders laud R&D subsidy provisions in the recently concluded General Agreement on Tariffs & Trade. **Page 7**
- Researchers caution that widespread use of plants genetically engineered to resist specific viruses could lead to creation of new plant pathogens. **Page 8**
- A Houston jury has ordered 3M and McGhan Medical Corp. to pay about $30 million to three women who claim to suffer ill effects from silicone gel breast implants. **Page 8**
- NASA begins a six-month campaign to study current and potential causes of ozone loss in the Southern Hemisphere, gathering data with aircraft based in New Zealand. **Page 9**
- FMC will begin the first phase of a two-part project that will significantly lower soda ash production costs by use of a new proprietary process. **Page 9**

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BUSINESS

Kenneth Minton, who transformed U.K.'s Laporte from a small bulk chemical company into a thriving specialty chemicals firm, receives Society of Chemical Industry's Centenary Medal. **Page 15**

Potential effects of broad patents on product development are analyzed in context of Calgene's progress toward commercialization of transgenic cotton. **Page 18**

GOVERNMENT

Ethical challenges to health care and technology transfer, presented by rapid advances in biotechnology, were discussed at a conference held at Rice University. **Page 20**

Closing down the Superconducting Super Collider may take four years and more than $1 billion—about half of that amount will go to close existing contracts. **Page 22**

SCIENCE/TECHNOLOGY

Causes and effects of scientific illiteracy are defined and explored by physicist and author James Trefil at a Pittcon '94 plenary session in Chicago. **Page 26**

PRIESTLEY MEDAL ADDRESS

DuPont senior science adviser Howard Simmons focuses on two issues he believes are central to the health of the chemical profession—maintaining a strong basic research effort and improving math and science education. **Page 27**

BOOKS

"Reflections on Symmetry in Chemistry .... and Elsewhere" gives a history of structural chemistry and crystallography as it examines the appeal of the symmetric in chemistry and art. **Page 70**

INSTRUMENTATION '94

Pittcon '94 mirrored a technology in transition, with many of the exhibits reflecting the continuing evolution of approaches to lab automation, growing installation of lab information management systems, and new activity in automated sample preparation. Page 32

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LETTERS

CHEMICAL SAFETY

Azide explosions discussed further

Peter G. Urben pointed out that "eschewing halogenated solvents will not eliminate azide explosions" (C&EN, Dec. 13, 1993, page 4). And if we stop reading his letter at this point, he is correct; however, the remainder of the statement and the letter are either incorrect or inappropriate to the facts we described (C&EN, April 19, 1993, page 4).

We cannot speak to the specifics of the explosion described by Victor J. Hruby, Lakmal Boteju, and Guigen Li (C&EN, Oct. 11, 1993, page 2), but in our case, we used a catalytic amount of sulfuric acid and a large excess of sodium azide. The reaction was poured into water and extracted with methylene chloride. After drying and filtering the organic layer, we concentrated it on a rotary evaporator.

The explosion took place after all the solvent had been removed and the flask was being detached from the steam tube. The detonation occurred in the flask; the evaporator was destroyed by the conclusive force of the explosion. We again point to the articles by A. Hassner et al. [*Angew. Chem. Int. Ed. Engl.*, **25,** 479 (1986), and *J. Org. Chem.*, **55,** 2304 (1990)] describing the synthesis and explosive potential of polyazidomethanes.

We believe strongly that diazidomethane and not hydrogen azide was the culprit in our explosion and that Urben should not attempt to change our conclusion. Our intent is to warn our colleagues of the dangers of producing this explosive chemical. We reiterate that because of this incident we no longer permit any chemical reactions with azide to be performed in the presence of a halogenated solvent in our laboratories.

Norton P. Peet
Philip M. Weintraub
Marion Merrell Dow Research Institute
Cincinnati

Nitric oxide reactivity

I would like to compliment Paul L. Feldman, Owen W. Griffith, and Dennis J. Stuehr on their interesting article "The Surprising Life of Nitric Oxide" (C&EN, Dec. 20, 1993, page 27).

However, I would also like to point out that a couple of phrases describing nitric oxide could be misleading. The first paragraph calls "Nitric oxide, NO—a small, relatively unstable, potentially toxic diatomic free-radical." The second paragraph discusses the molecule's reactivity.

In fact, nitric oxide is unusually stable and remarkably unreactive as a diatomic free-radical. Judging by the usual criteria for free-radical activity, nitric oxide does not abstract hydrogens from active hydrogen donors with carbon-hydrogen bonds; does not add to double bonds; does not dimerize or disproportionate extensively, if at all; and reacts relatively slowly with phenolic antioxidants. [See *J. Org. Chem.*, **58,** 3597 (1993) and *J. Chem. Soc. Chem. Commun.*, **18,** 1377 (1993)]. The reactivity of nitric oxide is largely associated with reactions with other radicals, as correctly pointed out by the authors, such as with superoxide anion radical, chelation with transition-metal ion centers such as iron, with oxygen and with phenoxyl radicals. However, in the latter case even radical coupling with nitric oxide-induced EPR line broadening is experienced with phenoxyl radicals as an event separate from chemical coupling, indicating remarkable intrinsic stability and lack of reactivity of nitric oxide in solution.

Although little fundamental reaction chemistry of nitric oxide appears in free-radical textbooks, it appears that nitric oxide may be very similar in stability and reactivity to oxygen (ground- state triplet dioxygen). Oxygen usually does not easily abstract hydrogens from carbon hydrogen bonds (at room temperature), does not add to double bonds, does not dimerize or disproportionate, and reacts relatively slowly with phenolic antioxidants. The reactivity of oxygen is mostly associated with reactions with other radicals or paramagnetic species although in the former case this reaction can also be reversible. Of course, nature knew of this similarity between oxygen and nitric oxide for a long time. How else could these two small molecules do the many wonderful things we expect them to do in biological systems?

Edward G. Janzen
Director, National Biomedical Center
for Spin Trapping & Free Radicals
University of Guelph, Guelph, Ontario

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INTELLECTUAL PROPERTY RIGHTS

Risk cuts flow of investment, technology

Investments in developing nations and transfers of technology to them by U.S. companies are heavily influenced by the strength or weakness of a nation's intellectual property protection, particularly in high-technology sectors like the chemical and pharmaceutical industries.

This finding—documenting with survey data, interviews, and statistical analysis what some observers had previously hypothesized—stems from a research project initiated by the International Finance Corp. (IFC), an affiliate of the World Bank and the largest multilateral source of loan and equity financing for private-sector projects in developing countries. The 51-page study was supported by the World Bank and prepared by Edwin Mansfield, director of the Center for Economics & Technology and professor of economics at the University of Pennsylvania.

"It's the first reasonably comprehensive, systematic study done," Mansfield tells C&EN. "There've only been partial studies with a bit of data in the past, and a lot of anecdotal accounts."

In 1991, Mansfield began to survey 100 major U.S. firms in six manufacturing industries: chemicals (including drugs), transportation equipment, electrical equipment, machinery, food, and metals. He obtained complete or partial data from 94 companies, a high response rate; 16 chemical firms participated, although not all answered all questions.

The effect of intellectual property protection depends greatly on the type of investment, the study finds. Only about 20% of the 94 firms say such protection is important for investment in sales and distribution outlets. For investment in rudimentary production and assembly facilities—involving basic technologies well known to firms in the industry—about 30% call protection important. About 50 to 60% say protection is important for investment in facilities to manufacture components or complete products, and some 80% call protection important for investing in R&D facilities.

Weak patent protection deters U.S. chemical firms overseas

	% deterred		
	Joint-venture investment[a]	Technology transfer[b]	Licensing[c]
DEVELOPING NATIONS			
Argentina	40%	44%	62%
Brazil	47	50	69
Chile	31	47	47
Hong Kong	21	21	33
India	80	81	81
Indonesia	50	40	73
Mexico	47	31	56
Nigeria	64	67	73
Philippines	43	47	47
Singapore	20	12	25
South Korea	33	31	38
Taiwan	27	19	44
Thailand	43	60	73
Venezuela	40	50	62
OTHER NATIONS FOR COMPARISON			
Japan	7	0	12
Spain	0	0	6

Note: Based on sample of 16 U.S. chemical and pharmaceutical firms for 1991 (not all firms supplied data for all countries). **a** Percent reporting that protection is too weak to permit investment in joint ventures with local partners. **b** Percent reporting that protection is too weak to permit transfer of their newest or most effective technology to wholly owned subsidiaries. **c** Percent reporting that protection is too weak to permit licensing of their newest or most effective technology to unrelated firms. **Source:** International Finance Corp. study by Edwin Mansfield

For investments other than in sales and distribution outlets by the six industries, the chemical industry has the highest percentage of firms that consider protection to be important. As might be expected, a high correlation exists between the industries' rank in this regard and their rank in previous studies on the importance of patents in the innovation process.

Mansfield asked each firm to indicate for 14 developing nations whether their intellectual property protection is too weak to permit three activities: investment in joint ventures with local partners (including contribution of advanced technology); transfer of its newest or most effective technology to wholly owned subsidiaries; or licensing of its newest or most effective technology to unrelated firms.

He selected the 14 nations because of their size and importance, as well as the frequency of their citation in controversies over intellectual property protection. For comparison's sake, the study added a developed country whose protection has aroused some controversy (Japan) and a relatively poor West European nation (Spain).

More than 30% of the U.S. firms believe intellectual property protection in India, Nigeria, Brazil, and Thailand is too weak to permit investment in joint ventures. Only 10% or fewer view Japan and Spain that way. The chemical industry, where patents are relatively important, generally shows the highest percent deterred—racking up figures of 80%, 64%, 47%, and 43%, respectively, in the four nations, for example. The metals industry generally has the lowest percent deterred (20%, 20%, 0%, and 0%, respectively).

Similarily, 30% or more of the firms say they would be unlikely to transfer their newest or most effective technology to a wholly owned subsidiary in India, Thailand, or Nigeria, but fewer than 5% react this way in regard to Japan and Spain. The chemical industry again has the highest percent deterred and the metals industry, the lowest. For instance, the percentage of chemical firms deterred reaches 81% for India, 67% for Nigeria, 60% for Thailand, and 50% for Brazil and Venezuela.

As for licensing a firm's newest or most effective technology to unrelated firms, more than 30% of the companies polled would be deterred from doing so in India, Brazil, Thailand, Nigeria, Indonesia, and Taiwan. Fewer than 10% view Japan and Spain that way. More than two thirds of the chemical firms say protection is too weak to permit such licensing in India (81%), Indonesia (73%), Nigeria (73%), Thailand (73%), and Brazil (69%).

Averaged over all six industries, nations perceived to have the weakest protection are India, Thailand, Brazil, and Nigeria. Those seen to have the strongest protection are Hong Kong and Singapore. Hong Kong and Singapore also rate best in the chemical industry.

Mansfield points out that there is a high correlation among a nation's standing in the three activities. Moreover, he notes, results for the chemical and pharmaceutical industry jibe with a Pharmaceutical Manufacturers Association list of countries with weak intellectual property protection.

Interviews conducted during the study with company officials cast more light on the results. For example, firms object to lack of patent protection for chemicals and drugs in India, Thailand, and Brazil. They also give poor ratings to Argentina (which denies patent protection to drug products) and Venezuela (which has denied patent protection to drug products or chemical preparations, reactions, and compounds). Chemical executives point out that chemical firms in these countries often can imitate new products relatively easily, a much harder task for companies in such industries as metals and transportation equipment.

An unidentified "president of a large chemical firm" explains that "intellectual property protection is especially important for those proprietary advanced technologies we have spent millions to develop, and which we feel provide the basis of our global competitive advantage. . . . The weaker we perceive a country's system for protecting intellectual property to be, the more likely we are not to transfer any leading-edge technology, whether through direct investment, joint venture, or license."

The study points out that steps have been taken recently to strengthen intellectual property protection in several nations, including South Korea, Mexico, and Taiwan. For example, a chemical company chairman says Mexico's 1991 law "can serve as a role model for many other countries." Mansfield reinterviewed some firms to see if attitudes are changing. So far, only Mexico shows a substantial rise in the percent of firms willing to transfer advanced technology: About 30% have changed their stand.

Copies of the report, "Intellectual Property Protection, Foreign Direct Investment, and Technology Transfer," IFC Discussion Paper 19, are available for $6.95 plus postage from the World Bank Publications Department, 1818 H St., N.W., Washington, D.C. 20433, or by calling (202) 473-1155.

Richard Seltzer

U.S. high-tech leaders laud GATT R&D clauses

The final draft of the General Agreement on Tariffs & Trade (GATT), approved last December in Geneva and top-heavy with impenetrable trade jargon, has begun moving through the Senate Finance Committee. Last week, a committee hearing aired reactions to the pact's once-controversial R&D provisions.

Those provisions had set off last-minute fireworks during the December trade talks (C&EN, Jan. 3, page 13). After frantic negotiations in Geneva, the U.S. delegation succeeded in convincing the other negotiators that it didn't really want what it had apparently supported for many months: limits on government support for research with industry or for research tied to industrial needs in government or academic labs. The whole caper underscored the perceptual mismatch between trade and technology policymakers in both the Clinton and Bush Administrations.

C&EN staff photo

Bloch: ensure green light stays off

Judging by testimony at the hearing from former National Science Foundation director Erich Bloch and from Mary L. Good, undersecretary for technology at the Commerce Department, things are now just hunky-dory.

Bloch, a distinguished fellow at the private Council on Competitiveness in Washington, D.C., says three improvements in the final draft stand out. First, it makes "clear and appropriate distinctions between fundamental research, industrial research, and commercial development research." These definitions are important because the U.S. wants to ensure that the green light stays off for government subsidies for development projects. The U.S. position always has been that development should be done only by the private sector.

Second, fundamental research is free from any limits at all. The earlier draft's language "was vague and imprecise," Bloch notes, while the new text's definitions and perspectives "are clear and specific."

Third—and this is probably the most crucial change—the new draft removes the requirement that subsidy recipients tell GATT overseers, up front, the objectives of research to be supported. Bloch points out that such a requirement would have "revealed to the GATT Subsidies Committee their research plans and technology road maps." U.S. companies prefer to keep their plans to themselves.

But Bloch admits that a couple aspects of the GATT draft still concern the Council on Competitiveness. "If abused," he says, these provisions "could conceivably cause adverse effects on our industries." The GATT organization must closely monitor the so-called green-light provision to see whether foreign competitors of U.S. firms are providing large subsidies for major projects like Airbus—the passenger airliner whose development subsidized by the French and British governments still causes rancor in the U.S. The result, he adds, could be distortion of markets. And "some of the provisions for pre-competitive development activity may be interpreted differently or even abused by other countries."

Rufus H. Yerxa, deputy U.S. trade representative, pledged at the hearing that the subsidies section will not become a "loophole under which other countries will be able to provide production or marketing subsidies."

Good also is pleased with the GATT pact. The Commerce Department's Ad-

SSC termination will be lengthy and expensive

Closing down the huge Superconducting Super Collider (SSC) is going to take a lot of time and money. Congress gave the Department of Energy $640 million to begin the shutdown in fiscal 1994, and DOE is asking for another $180 million next year. In the meantime, Energy Secretary Hazel R. O'Leary has come up with a termination plan for the project that will guide the department's activities.

Much of the expense associated with terminating the SSC project involves closing out the many contracts the department has for building and supplying the site. Other major parts of the termination will be the environmental restoration and asset closeout, and the benefits provided for the SSC's employees. Two things still unresolved are the settlement DOE must make with Texas for the state's investment in the project and deciding what will be done with the facilities already there.

Congress voted last year to close down the project as of October 1993. The consensus was that costs had escalated beyond reason and that the nation had other priorities for the funds. Originally thought to cost about $4.4 billion to build, the estimated cost had ballooned to $13 billion by last year. More than $2 billion had already been spent. Congress had also been told significant funding would come from other nations, especially Japan, to help with the project. However, only very minor funding was ever forthcoming from foreign sources, and Japan did not contribute at all.

Over the next four years, DOE plans to spend more than $210 million to close out the contracts and subcontracts it negotiated for building the SSC. The six major engineering contractors at the site are EG&G, PB/MK, GD-CDM, Babcock & Wilcox-CQM, Lockheed, and Westinghouse. These firms held combined contracts worth about $850 million at the time SSC was halted. Overall, the project has approximately 44,000 contracts out for everything from business cards to the manufacture of the superconducting magnets. There are also real estate leases and some international agreements that have to be completed.

PB/MK was the construction contractor at the site, responsible for the tunnels, buildings, and utilities for the SSC. Paul H. Gilbert, project director for the PB/MK team, says: "I think everyone was terribly disappointed" that Congress shut off funding for the project. "We are also disappointed because our part of the job had been going extremely well." The company had fixed-price contracts to spend $460 million, and at the time of termination was running nearly $100 million under budget, according to Gilbert. Despite already having a termination plan from DOE, Gilbert expects it to take up to two years before all the contract settlements are completed.

Taking care of personnel being laid off at the site is a major concern as well. About 2,200 persons, including scientists and engineers, worked in the laboratories at the site. According to DOE's SSC spokesman James Abbee, that number is already down to about 1,100, and likely will be reduced to 950 by the end of this month.

DOE is committed to providing outplacement assistance programs, job fairs, and other aid for workers who have been dismissed. DOE also will give 60 days' severance pay for those laid off at the laboratory. Most of the technical people—scientists, engineers, and computer specialists—are able to find work fairly quickly, Abbee says, but clerical personnel are having more trouble.

Gilbert indicates a similar situation at his company. "Placement has been a substantial problem," he says. His company is rapidly reducing staff, but has only been able to find new jobs within the company for about half of the people. The rest are finding positions at other companies or away from the site, with about 10 to 15% remaining unemployed, Gilbert says.

The question of how best to use the assets from the SSC site is to be the subject of a meeting March 22 at the SSC central facility. Interested parties are invited to suggest new uses for the facilities and equipment now in place. The SSC site already includes extensive cryogenic facilities; superconducting magnet tooling equipment; the Magnet Test Laboratory; a 550,000-sq-ft building including machine shops, labs, and liquid helium refrigerator; 15 miles of tunnels; and an integrated network of distributed computer workstations. Also at the site are a negative hydrogen ion source and the first stage of a 2.5-MeV linear accelerator.

"Secretary O'Leary has to report back to Congress by July 1 with recommendations as to what to do with the SSC assets," Abbee says. That does not give DOE much time. Texas Gov. Ann W. Richards has formed an advisory panel to advise her on future use of the site, and the panel is discussing ideas with DOE, too, according to Abbee.

A major expense to the government not included in the estimate of the termination plan is reimbursing Texas for the money it has spent at the site. Texas and DOE have signed an agreement to negotiate in good faith on this issue. Texas claims it has spent $435 million directly on the SSC and has said that it wants to be reimbursed for that amount, in cash. "This is being negotiated at this time," Abbee says. Adding this amount to the amount already spent and projected termination costs would raise the government's tab for halting the SSC to more than $1.1 billion.

David Hanson

Contractors take biggest chunk of funds for Superconducting Super Collider termination

$ Millions	1994	1995	1996	1997	Total
Contract closeout	$141.4	$ 66.6	$ 3.7	0	$211.7
Personnel demobilization	71.3	17.2	1.9	$ 0.3	90.7
Technology closeout	33.9	2.0	0	0	35.9
Facility maintenance & security	22.6	10.5	0	0	33.1
Administration & support	17.6	13.5	0.7	0.7	32.5
Asset phaseout[a]	11.0	8.2	57.8	57.6	134.6
Environmental safety	7.7	7.6	0	0	15.3
Economic development & use	3.6	1.5	0	0	5.1
TOTAL	**$309.1**	**$127.1**	**$64.1**	**$58.6**	**$558.9**

Note: Cost estimates do not include $51 million spent in fiscal 1993, nor do they include future settlement with Texas. [a] Includes site restoration. **Source:** Department of Energy

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Researchers explore applications to chemistry
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CHEMICAL & ENGINEERING NEWS

C&EN

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NEWS OF THE WEEK

- New treatment for diabetes, involving implantation of encapsulated insulin-secreting cells in a patient, passes first clinical test. **Page 4**
- EPA approves—with unusual strong strings attached—marketing in the U.S. of acetochlor, an herbicide classified as a potential human carcinogen. **Page 5**
- Seaborgium is proposed as the name for element 106, honoring Nobel Laureate Glenn Seaborg. **Page 5**
- Russian officials drop all charges against chemist accused of divulging state secrets about chemical weapons research. **Page 6**
- The 207th ACS national meeting in San Diego attracts more than 14,000 attendees. **Page 7**
- Miles complements its product mix by acquiring ChemDesign, a custom fine chemicals producer, for about $105 million. **Page 7**
- New type of gallium arsenide transistor is fabricated based on gallium sulfide insulator. **Page 8**

COVER: Operator uses head-mounted display and force-feedback handgrip to explore a graphite surface at atomic resolution with a scanning tunneling microscope. Photo by Alex Treml Photography, courtesy of the University of North Carolina, Chapel Hill, department of computer science

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BUSINESS

European fiber makers face increasing competition from the Far East as a result of many textile manufacturers moving there; the solution, industry group says, is slimmed down operations with focus on higher value added and specialty fibers. **Page 11**

French chemical industry will regain some momentum this year, with production increasing about 2% over last year's 1.3%, largely on the strength of the pharmaceuticals sector. **Page 14**

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Workshop on Electric Field Effects in Multicomponent Systems will be held in May; a poster session is planned. **Page 33**

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The application of virtual reality—a computer-generated 3-D environment—to chemistry is allowing scientists to visualize and interact with chemical systems in new ways. Page 22

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LETTERS

Benefits of eye protection

Letters to the editor by Jay A. Young and John M. Hoffman (C&EN, Feb. 7, page 3), deal with legalities that do not require the wearing of eye protection "when nothing dangerous in going on." Somehow this seems to put down the proven benefit of wearing eye protection in all situations where there is any potential for eye injury.

DuPont and other leading industrial firms half a century ago began requiring eye protection at all times in factories and laboratories. Academics were slow in adopting this practice, but it now is universally accepted—at least in chemistry laboratories. Surely any eye injuries in academic or industrial laboratories, no matter how unexpected the accident, will result in penalties for management if the routine wearing of eye protection has not been enforced.

Malcolm M. Renfrew
Emeritus Professor
University of Idaho,
Moscow

Sperm count speculation

Bette Hileman's article "Environmental Estrogens Linked to Reproductive Abnormalities, Cancer" (C&EN, Jan. 31, page 19) claims "sperm counts in men worldwide have fallen about 50% since 1940."

This is the kind of scare tactic that helps to get funds for governmental and environmental agencies. While the chemical structure of the active ingredient of marijuana is noted, the article does not report on the effects it has on the male.

The exposure to marijuana has increased since 1940. By 1988, the National Institute of Drug Abuse reported that there were 11,616,000 users of marijuana. These individuals were repeatedly exposed to extremely high dose levels of this natural estrogen. This compares with the parts per million or parts per trillion or less exposure to compounds such as DDT, DDE, and Kepone, which the article suggests cause abnormalities and cancer.

J. B. Webber of North Carolina State University reported in *Weeds Today* (Spring 1979, page 22) that the active ingredient in marijuana accumulates in body tissues and fluids. This is similar to many of the compounds that caused the concern by the scientists in Hileman's article.

Alcohol, which is usually consumed along with marijuana, is also known to have a similar effect on males. Therefore, you have a combination of exposures affecting male virility.

Why must environmentalists constantly bash decades-old pesticides and related compounds to support the hypothesis that the chemical industry has polluted the world?

Let's study and report on the real cause of lower male sperm counts—marijuana.

Raymond W. Luckenbaugh
Gettysburg, Pa.

No environmental conspiracy

As a professional chemist for almost 15 years, and an active participant in the "environmental movement" for over 20, I feel compelled to respond to Fred Tausch Jr.'s letter (C&EN, Jan. 31, page 5) and to some of the responses to it.

Tausch makes it sound as if the environmental movement is some organized conspiracy aimed at the destruction of the chemical industry and the American way of life. I know of no such conspiracy, even though I was the vice-chairman and then chairman of the local Sierra Club. In fact, the term "environmental movement" is somewhat false, as if Nature Conservancy, Sierra Club, Greenpeace, and Earth First! are all perfectly united with the same political agenda. They are, as Carlyle Herrick (C&EN, Feb. 21, page 2) discussed, united in the idea that a clean environment is the obligation of the human race as residents of this planet. But, as with the rest of the political spectrum, there is great disagreement as to the best means to achieve this goal.

I do find one similarity between many people in these environmental groups and many people in the chemical industry: a great distrust of the people on the other side. That is the fundamental problem. We do not need ACS to take on an adversarial position. Only by having environmentalists and chemists work together will we begin to solve these complex and important problems.

Jonathan W. Foise
Mentor, Ohio

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Growing Competition from Far East Troubles European Fiber Makers

■ ***Industry group sees solution as trimmer producers focusing on higher value added and specialty fibers***

Patricia L. Layman, C&EN London

Given the inexorable move of textile makers to the Far East and other developing economic areas, is there a future for the fiber manufacturing industry in Western Europe? Yes—but in a slimmed down version that concentrates on higher value added and specialty fibers. That's the message from CIRFS, the International Rayon & Synthetic Fibers Committee, in a C&EN interview with its new director general and in a report the organization is publishing this spring via the U.K. publisher, Economist Intelligence Unit.

Charles Gupton/Uniphoto

Cloth dealer in a market in China, which is becoming a major supplier to world markets.

And it means that, for chemical suppliers to the fiber industry, the task will be to keep an eye on quality and specialty demands by their customers—and to prepare to hedge their bets with investments in the Far East, as well as in their traditional areas.

Key to the problem facing the Western European fibers industry is the move of many of its customers—textile makers—to the Far East. Not only are labor costs low there, which is important for labor-intensive textile and apparel manufacturing, but also national governments regard these industries as strategically important, capable of employing large numbers of the population and generating hard currency from exports.

This is not a newly emergent problem, of course. In May 1988, officials at DSM Chemicals in the Netherlands were already noting the shift of synthetic fiber production to newly industrialized countries and its consequences for European producers of fibers and fiber raw materials.

But the problem has intensified since then. In just one end-use sector—spun yarns, which make up more than half of the Western European fibers market—fiber consumption has been falling since 1987, from some 3.3 million metric tons in that year to just below 2.9 million metric tons in 1991.

Further declines are expected in Western Europe during the 1990s, the result of increasing access of apparel products made in developing countries reducing the demand for domestically produced textiles, and the lack of export opportunities for textiles made in Western Europe. The outlook is for a 10 to 20% fall in fiber consumption for the manufacture of spun yarns during this decade.

In contrast, production and consumption of spun yarns, particularly for cotton and cottonlike textiles, are expected to increase significantly in Asia in the 1990s. In China, for example, a 35% growth in production is forecast during this decade, and in the Indian subcontinent, increases in India and Pakistan of 25% and 22%, respectively, are expected. Production gains are also likely in Indonesia, the Philippines, and Thailand during the first half of the decade, and in Malaysia, Bangladesh, and Vietnam in the latter half of the 1990s.

Despite those basic trends, however, there is still a significant role for producers of both fibers and textiles in Western Europe, contends Colin Purvis, who was appointed director general of CIRFS in January. He succeeds Jean-Louis Juvet, who had headed the organization for 27 years, including its recent move from Paris to new headquarters in Brussels.

Purvis, formerly secretary general of the British Apparel & Textile Confederation, has taken over a small but impressively effective organization that represents an industry that experienced radical restructuring in the 1980s and is still troubled by overcapacity. It is, as the representative of one member company says, "run [by] a tiny handful of professionals, all of whom have to be very good at what they do. CIRFS is the best organization we belong to."

CIRFS members include nearly two

dozen companies producing synthetic and cellulosic fibers in Western Europe—essentially those countries in the European Union, the Nordic countries, and Austria and Switzerland. The members account for about 90% of manmade fiber production (excluding polypropylene fibers, production of which is structured differently than that of other synthetics) in Europe. Membership ranges from relatively small fiber-producing specialists to the fibers divisions of major chemical companies.

CIRFS' staff of 10 covers three main areas: statistics, technical and environmental affairs, and economics and lobbying. Technical and environmental affairs are becoming increasingly important. For example, CIRFS is contributing industry input into a debate on whether or not there will be a European Union-sanctioned Eco-label (environmentally friendly approval label) for textiles, and if so, what criteria should be used.

Probably the organization's most visible role, however, is analysis of economic issues. This activity enables CIRFS to back up its presentations to various governmental and trade bodies, on both a national and multinational basis, and to keep members up to date on what's going to affect them.

CIRFS took a fairly active role, for example, in the Geneva negotiations on the General Agreement on Tariffs & Trade (GATT), working with its textile manufacturers counterpart associations. High on the agenda: dumping actions and unfair barriers to trade.

Trade issues within Europe are also one of the major concerns of CIRFS, particularly the need for a level playing field regarding national government subsidies. Currently, a framework agreement with the European Commission covers national subsidies or investments in the manmade fibers industry. And this, says Purvis, "we feel needs to be maintained." According to the framework, the commission must be notified in advance of all government subsidies to the synthetic fibers sector, and any subsidy assistance for increasing capacity is forbidden. Where subsidies are granted for modernization, the funds should be linked with restructuring and reducing capacity, Purvis explains. In that way, he argues, "market forces will direct the industry structure, rather than government intervention.

"Our industry is 'chemical' in its capital intensity—the economics favor running at full blast whenever you can. But we are serving textile markets, which are highly cyclical. It is difficult to run during downswings on the textile side. Therefore, an artificial creation of capacity [from government subsidies] would be extremely damaging to the health of the sector."

The fibers industry is currently in the downswing of the business cycle, he says, and has been since 1991. However, "There are some signs that the situation is not as bad as it was, although recovery is not quite here. But recovery there will be," he emphasizes.

That's the short-term situation. "Long term, you have to look at more structural factors about our industry and our customers' industries. One factor affecting our industry is that certain types of textile production are migrating to other parts of the world, particularly with low labor costs," he concedes. "Some 40% of manmade fibers go into clothing. Therefore that has important implications for us."

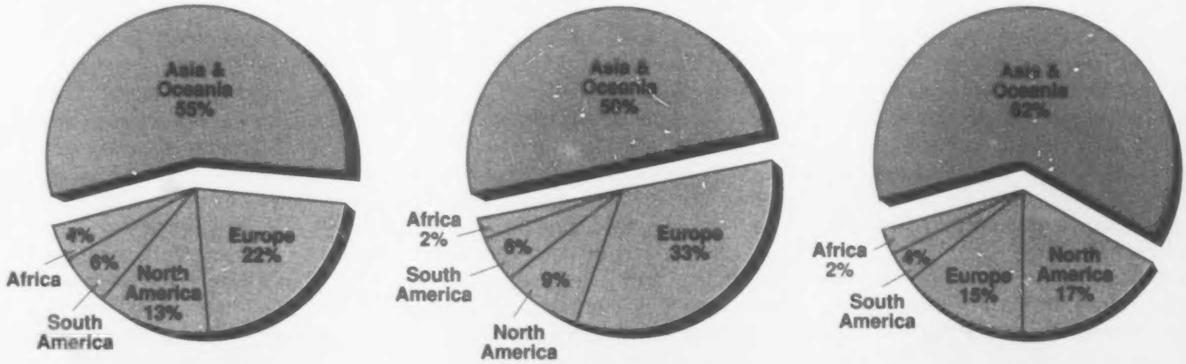
However, he is convinced that, in the apparel sector, "not all European production will migrate. There are always advantages in being close to the market—quality of service, quality of design, and so on, for which you can charge a premium." Also there are some tariff advantages for imports of textiles that use European fibers.

"Yes, there will be a market for fibers in Europe. Our customers are probably looking for materials with higher value added specific qualities. There is no reason to believe that the Western European industry is not capable of providing those fibers to the clothing industry in Europe. In volume terms, the market won't be as large, but there will still be a strong market for fibers for clothing."

Other sectors will be even healthier—household textiles and carpets, for example. And one sector—industrial fibers—is a solid growth area. These fibers are used in a variety of products, such as tires, geotextiles, and nonwovens, all linked to the state of the general economy. Imports of these fibers have been low: For many purposes, the producer must engineer them for specific uses. Industrial fibers cost more to produce, but give higher profit margins.

The imbalance of trade in fibers and fiber-consuming products, however, will continue to be a factor influencing the Western European industry. And, as Pur-

Far East dominates world consumption of staple fibers



1993 cotton fiber yarn use = 15.5 million metric tons

1993 cellulosic fiber yarn use = 1.46 million metric tons

1993 synthetic fiber yarn use = 4.74 million metric tons

Note: Yarns in above figures are short staple. **Sources:** CIRFS (International Rayon & Synthetic Fibers Committee), C&EN estimates vis notes, although the Uruguay round of the GATT negotiations did provide some positive new opportunities, there were some disappointments, too. For example, some potentially large markets for fibers have remained essentially closed. India, for one, will maintain tariffs of more than 100% on fibers; European tariffs are being trimmed to about 4%. Tariffs will remain high as well in Pakistan and Indonesia, and, although they will decrease in other Southeast Asian countries, the decline will extend over a decade and will still wind up at about 30 to 35%.

Entry to markets is one reason textile manufacturers, in particular, are heading east. Another reason is lower costs—especially labor costs.

Low labor costs must be buttressed by a reasonable infrastructure in a country. A company manager contemplating where to locate a plant, for example, would want docks from which to ship fibers; a governmental administrative and legal system sympathetic to businesses; and a reasonable level of education of the work force, as well as a work force that can be motivated.

CIRFS addressed the question of low labor costs in a report issued last May, "The Prospects for the Production of Spun Yarns During the 1990s," which is providing the basis for a new report due out soon. This study was an attempt to look at the prospects for fiber makers by examining a major market sector for fibers: spun yarns, which account for slightly more than half of total world production of both natural and man-made fibers. Spun yarns are used in apparel—cottons, cotton-polyester blends, wools, and the like—as well as in carpet and household textiles. They also have a wide variety of industrial textile applications.

The CIRFS report points out that many factors besides direct labor and production costs can make the difference between a thriving or dying textile industry in any given country. Italy's spinning industry, for example, continues to be buoyant, although that country has the highest indirect charges as a percentage of gross wages and one of the highest total labor costs in Western Europe.

In contrast, in the U.K., where labor costs compare favorably with most other developed countries except for Spain, Portugal, Greece, and Hungary, the textile industry has virtually disappeared over the past decade. The reasons: a highly concentrated retail structure and a laissez-faire political stance on trade policy issues, resulting in rising imports of yarns and fabrics at very low prices that have swamped the domestic textile industry.

The report concludes that labor costs are not the only significant factor in any comparison of production costs among various Western European countries, but they are probably the prime consideration in the garment sector, in particular, outside Western Europe. In Europe, for example, labor accounts for some 46% of total costs, compared with 7% in Indonesia.

However, the picture is always changing. The study points out that figures confirm the relocation of industry away from the newly industrialized countries where wage costs are rising—for instance, from South Korea and Taiwan—toward even lower wage-cost countries such as Indonesia, Sri Lanka, India, and China. And it is in those countries that producers of man-made fibers see their export chances as slim.

That is particularly frustrating to Western European fiber makers, because man-made fibers are increasing their share of market in developing countries.

In the spun-yarn category, the CIRFS study notes, cotton is still the major single fiber worldwide, given its predominance in countries like India and Pakistan. However, though man-made fibers now account for more than one third of the total spun-yarn market in Western Europe, in developing countries, including those with centrally planned economies, the share of man-made fibers has reached nearly 40%. In China, the world's largest cotton producer, man-made fibers' share of total fiber consumption has grown from 10% in 1975 to more than one third at the start of this decade.

In 1970, in Western Europe, synthetic fibers accounted for only 20% of all fiber in spun-yarn production, the same percentage as wool; cotton had a market share of nearly 50% and cellulosic fibers had a market share of 13%. By the mid-1980s, both cellulosics and wool had lost significant ground to synthetics, while cotton's position had stagnated: Synthetic fibers accounted for about one third of all fibers in spun-yarn production.

More worrisome for man-made fiber producers in Western Europe, however, is the fact that since the mid-1980s, synthetic fiber consumption for spun-yarn production has fallen back to the levels of the late 1970s, and further declines are expected during the next 10 years. The main reasons are external factors such as the changing tariff structures and increased imports of apparel, primarily made from cotton. By the year 2003, free access will be permitted into the developed market economy countries, the CIRFS report points out.

One of the major exporting countries is China, where fiber consumption for spun yarns grew by two thirds in the 1980s. Demand for raw cotton rose about 1 million metric tons, broadly in line with the growth in cotton production. However, use of synthetic fibers has skyrocketed. In the 1980s, production of nylon rose 310% to 130,000 metric tons per year; polyester staple went up 421% to 602,000 metric tons per year; and acrylic fiber rose 111% to 122,600 metric tons per year.

What's more, man-made fibers get high emphasis in the current five-year plan, although cotton by volume will remain the largest fiber. By 1995, CIRFS predicts, man-made fiber consumption will reach 2.6 million metric tons per year, of which 2.1 million metric tons—500,000 above the 1990 level—will be produced domestically. And by the year 2000,.consumption is expected to be 3.5 million metric tons, of which 85% will be manufactured domestically.

Joint ventures with companies in Hong Kong, Japan, the U.S., the Philippines, and Singapore, and the incorporation of Hong Kong into China in 1997 will act as a spur in the quality of fabrics and apparel produced, to ensure that China continues to earn hard currency.

A case in point is the agreement between DuPont and China Worldbest Development Corp. (majority owned by the China National Textile Council) to explore the possibility of a joint venture to make and market Lycra elastane fibers in China, announced two weeks ago. According to DuPont, Lycra can be combined with many fibers being used in China such as cotton, nylon, wool, and silk to enhance the fit and shape retention of garments. DuPont already has Lycra plants in Japan and Singapore and recently doubled its capacity for the fiber in Singapore.

And BASF disclosed at the beginning of this month that it plans to build another plant at its site in Pudong, Shanghai's industrial zone, as part of its joint venture, Shanghai BASF Colorants & Auxiliaries Co. This plant, which will make 25,000 metric tons per year of textile and leather auxiliaries, follows the announcement last November of a 3,000-metric-ton-per-year plant for cationic textile dyes, and of an earlier plant to make 6,000 metric tons per year of pigments. All the plants are part of an investment totaling about $170 million.

As CIRFS concludes in its study: "In order to maintain their involvement in the sector, it may be increasingly necessary for Western European man-made fiber makers to relocate their manufacturing capacities nearer sources of low labor costs, not given the level of labor costs involved per se, but rather to be nearer major sources of apparel manufacture, which could subsequently be exported to Western Europe." Such an argument would obviously also apply to man-made fiber producers in the U.S., Japan, Taiwan, and South Korea.

For the Western European fiber maker, the future is one of changes. Fiber makers, and their chemical raw-material suppliers, will have to be nimble in meeting new demands—from whatever geographical direction. As CIRFS' Purvis puts it, "The needs of the industry tomorrow are not what they are today—let alone yesterday." ☐

French chemical industry to pick up this year

Output of the French chemical industry was up 1.3% last year over 1992, despite the generally depressed economy. Production in 1994, however, is expected to increase by about 2% over last year, compared with an average increase of about 1.5% in chemical output predicted for Western Europe. The pharmaceuticals sector will bolster the French industry, whose total output otherwise would be up only about 1%.

Those were among the statistics presented earlier this month by the Union des Industries Chimiques (UIC), the French chemical industry association, in what was an encouragingly optimistic briefing session.

Chemical sales, however, did not show the same pattern as production, slipping 1% last year from 1992. Had pharmaceuticals been excluded from total sales, the decline would have been 2%. The difficulties of the chemical industry in 1993 resulted much more from the drop in selling prices—although the decline varied markedly in the various product sectors—than from any drop in production.

The gloomy economic situation took its toll on the chemical industry throughout Europe. European chemical production as a whole had been up 2.6% in 1992 over the previous year, but fell 1.4% last year. The consolidated decrease was caused by drops in production of 3% in both Germany and Italy, and of 1% in Spain; it was only partly offset by the 1.3% increase in production in France and by 3% in the U.K.

The general European recession slowed the growth in production of the French chemical industry from a rate of 5.5% in 1992. It also put a damper on capital spending, which declined slightly, and it accelerated job losses. From October 1992 to October 1993, the chemical industry shed 1.3% of its employees, down to roughly 260,000 employed; in the comparable period in 1992, the decline had been only 0.3%.

One problem that continued to confront the French chemical industry last year was that, although output still grew, overall French industrial production dropped 4% from 1992. This affected end-use markets, causing a number of sectors to register declines in production: electronics, down 2%; metal industry, 5%; textiles, 7%; machine industry, 8%; and automobiles, 14%.

However, growth in chemical industry production is expected to continue to outpace that of general industrial production, predicted Francis Bazile, president of the UIC, as substitution of chemical products for nonchemical components continues—engineering plastics for metal, for example, in autos. Moreover, he pointed out that a considerable portion—40%—of chemical production is destined for consumption in households, and that these markets don't fluctuate as much as industrial ones.

Pharmaceuticals pace chemical output in 1993

Sector	% change from 1992
Inorganic chemicals	–7.0%
Basic inorganic chemicals	
Fertilizers	
Organic chemicals	1.5
Basic organic chemicals	
Pharmaceutical intermediates	
Plastics	
Synthetic rubber	
Essential oils	
Specialty chemicals	1.0
Soaps, detergents	
Coatings, inks	
Agrochemicals	
Photographic products	
Perfume, cosmetics	
Miscellaneous specialties	
Pharmaceuticals	4.7
TOTAL	**1.3%**

Source: Union des Industries Chimiques

The French chemical industry was also able to find some cheer in its trade performance. The surplus trade balance for French chemicals last year is estimated to amount to $6.49 billion, up from $4.50 billion of 1992.

UIC's economists noted that the trade figures are provisional. Because of a change in the way that countries within the European Union (formerly called the European Community) now collect statistics on intra-EU trade, trade figures "are difficult" to obtain properly. As the methodology is improved, however, statisticians predict that confusion will end. They forecast that final figures for the French chemical industry's trade balance will be lower than current estimates, but still about $5.40 billion. As one UIC staffer put it, "That is still very good."

Last year's capital spending by the chemical industry was more than $3.42 billion, some 5% of total sales. That was down about $290 million from the amount invested in 1992—not surprising, given the existence of overcapacity in various sectors of the industry and the mediocre outlook for demand in 1994. Capital spending in 1992 marked the second decline in a row from the record $4.18 billion the industry spent in 1990.

Roughly 40% of capital spending in 1993—$1.3 billion to $1.4 billion—was devoted to environmental and safety measures, up slightly from that of 1992. And keeping at least level with 1992, spending on research and development was $4.14 billion, or 6% of sales.

After managing to withstand the unfavorable business conditions during 1993, the French chemical industry will have a limited recovery this year, UIC economists predicted. However, they added that the recovery depends on certain essential factors, including the reduction of short-term interest rates, "which penalized the economy in 1993", a stronger dollar, making things more favorable for European exporters; and a continuing low price of oil and, consequently, of many of the industry's raw materials.

Patricia Layman

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CHEMICAL & ENGINEERING NEWS

C&EN

APRIL 4, 1994

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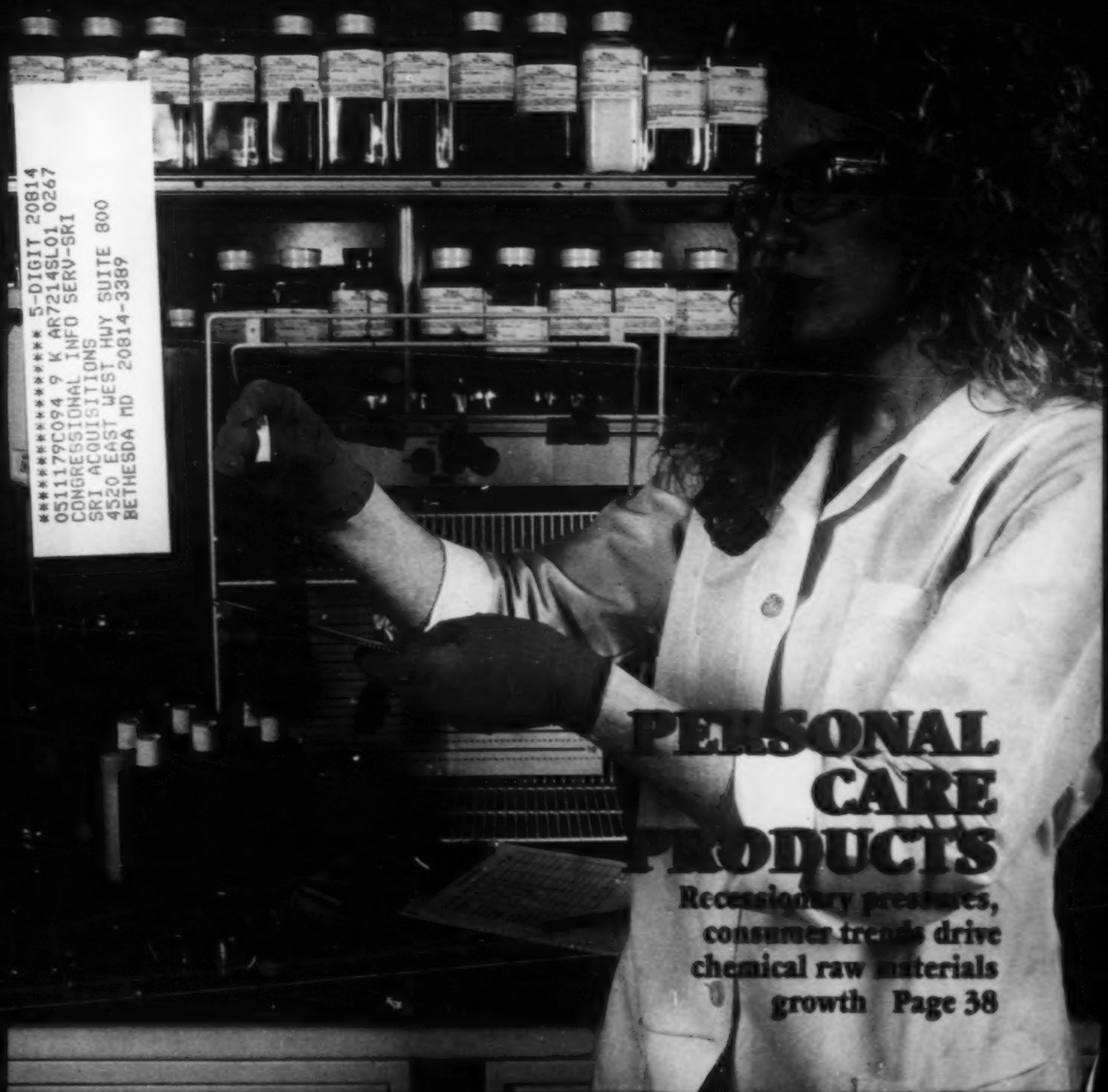

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PERSONAL CARE PRODUCTS

Recessionary pressures, consumer trends drive chemical raw materials growth Page 38

CHEMICAL & ENGINEERING NEWS

C&EN

APRIL 4, 1994

NEWS OF THE WEEK

- Artificial protein that binds four heme groups in a well-defined conformation is designed and synthesized for the first time, should facilitate study of how complex respiratory and photosynthetic systems work. **Page 4**
- FDA is considering regulating nicotine content of cigarettes and is collecting evidence on whether cigarette makers are manipulating levels of the addictive substance in their products. **Page 5**
- Ceremony designates Chandler Laboratory at Lehigh University as the second National Historical Chemical Landmark. **Page 6**
- Adopted despite U.S. objections, an international agreement, effective immediately, bans all exports of hazardous wastes from industrialized nations to developing countries. **Page 6**
- First R&D foundation established by the Chinese government and a foreign company—Ford Motor Co.—selects the first 25 projects that it will fund at 16 Chinese institutions. **Page 7**
- Shanghai Chlor-Alkali Chemical, a Chinese firm, has begun offering shares of its stock for sale in the U.S. **Page 7**

COVER: Witco researcher conducts hair swatch evaluation at company's research and technical lab in Dublin, Ohio

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BUSINESS

Biotechnology industry made modest strides last year despite widely fluctuating stock prices caused by investor uneasiness and products that didn't pan out in the marketplace. **Page 15**

Business Insights: Chemical productivity rose in 1993, but not as much as expected considering the reorganizations, work force reductions, and other cost-cutting steps taken by the industry. **Page 18**

GOVERNMENT

Education, environmental issues are being discussed and debated in Congress. ■ NIH is collecting feedback on its first test of a triage system to reduce the burden of reviewing grant applications. ■ Competitiveness outlook for environmental technology is explored in a government report. **Page 20**

SCIENCE/TECHNOLOGY

From the ACS meeting in San Diego: Developments in membrane technology are providing a better understanding of how membranes work. ■ Finding chromophores suitable for electrooptic polymers is the goal of several research groups. ■ Scientists take issue with the public perceptions of risk at a symposium on food safety evaluation. ■ Microalgae are a potential source of lipids that could be converted into a diesel fuel substitute. ■ Efforts to develop acetylene-based resins for thermoset composites, coatings, and fibers are making headway. **Page 25**

Proposals for research on drinking water are being solicited by a foundation that has $4.7 million for new projects in 1994. **Page 30**

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From the ACS meeting in San Diego: Chemical educators weigh merits of adding environmental theme to college chemistry courses. ■ Chicago-area high school teachers group uses imaginative demonstrations to attract students to science. **Page 34**

ACS NEWS

ACS Council and Board met in San Diego to deal with dues, presidential slate, and subscription prices. **Page 50**

PRODUCT REPORT

The mature personal care products market is prompting many companies to turn to their suppliers for more creative and better performing ingredients, help in new product development. Page 38

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LETTERS

Certification is not the answer

Larry Fink hits the nail on the head with his first paragraph (C&EN, Feb. 28, page 2). Yes, there are real opportunities for clever chemists who can devise better ways to do chemistry. Unfortunately, he writes seven more paragraphs that have nothing to do with clever chemistry. He proposes legislation that would add more red tape for government and industry, further diminishing the efficiency of both. He would require a "certified" professional chemist and professional engineer in order to manufacture, formulate, store, use, recycle, or dispose of any chemical.

"Political clout" is not the road to job security. The autoworkers unions once had tremendous political clout, but the marketplace bypassed them and exported a huge segment of the auto industry to other countries. Unless such rules can be imposed on the entire planet, they would simply put U.S. chemists and their employers at a competitive disadvantage. Go back to that first paragraph of Fink's letter, and do creative things with chemistry—creating something of value will bring you much closer to economic security.

D. Eric Walters
Vernon Hills, Ill.

Environmental policy

Opinions recently expressed on environmentalism by readers (C&EN, Feb. 21, page 2) confirm my hypothesis that highly educated people are not necessarily good policymakers. Any good policy should manage risk to an acceptable level based on a cost-benefit analysis. The crux of the issue is whether or not current environmental policy is managing low-risk activity at high cost.

One reader asserted that all "species . . . living in the world [work together] . . . to jointly create a benign environment wherein all species escape the threat of extinction." Tell that to the dinosaurs! Charles Darwin had a distinctly different view of nature—more along the "dog-eat-dog" theme. It is ironic that James Burke ["The Day the Universe Changed," BBC TV] asserts it was the very fact that species were found to have gone extinct naturally—which conflicted with then-dominant Western religious beliefs—that inspired the environmental studies leading up to Darwin's theories on evolution and modern environmentalism. The reader seems to claim that human activity currently is somehow exempt from Darwinian forces. Basing policy on the flawed environmental "religion" that human activities are beneath (or above) and not part of nature may result in a reprise of the Dark Ages, a period when thought itself was based on constructs that did not survive the light of logic.

Not all natural wastes "degrade." Crude oil certainly is toxic to the environment. The important point is the time frame over which a waste degrades versus how fast it accumulates adverse affects. The purpose of environmental expenditures ought to be to reduce the production rate or increase the degradation rate (natural or otherwise) of wastes in relation to their risk production rate; that is, to strike a balance. Higher consequence scenarios should justify high expenditures. Accordingly, incineration of hazardous wastes (a high-cost activity for a high-risk/low-probability combination) and sanitary treatment works (a high cost for a low-risk/high-probability combination) make sense; whereas, elimination of fluorocarbons (a high cost for an unknown risk with an unknown probability) may not make sense.

I fear the day when highly technical "experts" are allowed to keep the rest of us in politically correct Dark Ages.

Craig M. Oppat
Fort Washington, Pa.

Space station's purpose

There seems to be a misunderstanding regarding the space station. It is not a science project, it is an engineering project. Although some useful science will undoubtedly be done, that's not the primary purpose of the space station. Its primary purpose is to start developing the technology to settle space. Why is that important? There are several reasons, but the main one is this: Space is where humanity is headed next. A review of and extrapolation from human history and prehistory indicates that, so we might as well pave the way. That's the role of the space station, and its merit should be judged on the basis of how effectively it addresses that need.

Robert Legrand
Austin, Tex.

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Biotech Industry Makes Progress Despite Difficult Year in 1993

Pressures on stocks, health care reform, and product setbacks added to challenges facing the industry last year

Ann M. Thayer,
C&EN Northeast News Bureau

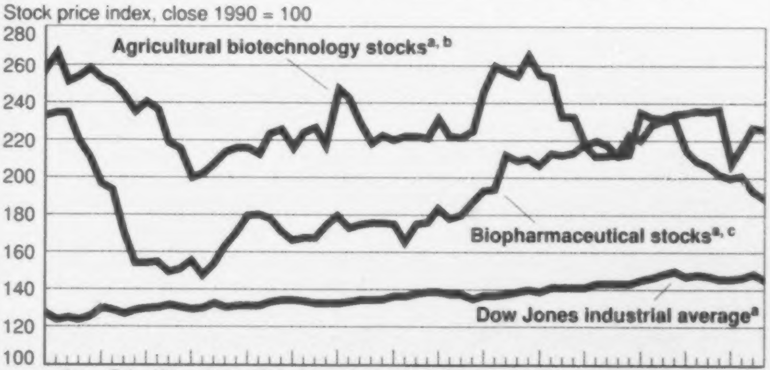
For the biotechnology industry, last year's worries were epic in more ways than one. The most public exposure of the technology, unfortunately for the industry, was in movie theaters with the film "Jurassic Park." Even worse, while biotechnology was depicted in a bad light on the big screen, health care reform was the real life *Tyrannosaurus rex* running rampant over the industry's parkland.

Fearful of the health care reform behemoth, investors at times were scared away from buying biotech stocks. Stock prices neared all-time highs and plummeted to all-time lows. And, while a few new products made their debut on the market, others long considered very promising faced significant setbacks. Despite the downturns, however, the year had an upbeat ending with hopes that things would get better in 1994. Now early into the year, it is not clear that they will.

In many ways, 1993 differed little from 1992 (C&EN, March 29, 1993, page 17). Again revenues and product sales grew for many companies, but only a handful of the same companies reported profits for the year. And, in the performance of biopharmaceutical stock values, the year was a near repeat of 1992, moving quickly from early highs to dramatic lows, followed by a gradual comeback throughout the remainder of the year.

The C&EN stock price index for biopharmaceutical companies started 1993 within a few points of what would be the yearly high of 237 (close 1990 = 100). This mid-January 1993 peak, part of a positive trend seen in late 1992, was the nearest the index would come to the all-time high of 264 reached a year earlier. Throughout 1993, the agricultural biotechnology stock index continued to fluctuate widely around an average of about 230, while the Dow Jones industrial average rose slowly, but steadily.

Biotechnology stock prices fluctuated widely in 1993



a Reindexed to show relative change. Prices as of Friday close each week. **b** Based on stock prices for Calgene, Crop Genetics, DNA Plant Technology, Ecogen, and Mycogen. **c** Based on stock prices for Amgen, Applied Bioscience, Biogen, Centocor, Chiron, Cytogen, Genentech, Genetics Institute, Immunex, Repligen, and Xoma.

The early 1993 peak was short-lived, largely because of two events that managed to shake the whole industry, which was already unsteadied by concerns about health care reform: In late February, Synergen disclosed that its leading drug candidate, Antril, did not perform well in clinical trials, and Amgen reported that first-quarter earnings would be 10 to 15% lower than expected (but still about 20% higher than a year earlier). Synergen's product was the third antisepsis product to disappoint—Xoma's E5 failed to impress the Food & Drug Administration in 1992, and Centocor's Centoxin was pulled from the European market and from U.S. clinical trials in January.

The C&EN biopharmaceutical stock index dropped 35%, hitting 154 in late February and remaining there for about two months. In late April, stock prices started to rise again and the index hovered around 175 until autumn. It then rose again, driven largely by marketing approvals for two new products, to end the year back in the low 220s.

Now the question is whether the cycle will occur a third time—in 1994. The biopharmaceutical stock index again reached a 12-month peak of 232 in late January. But stock values have been falling, down 19% by late March, and fell most recently on the news that Regeneron's leading product, for amyotrophic lateral sclerosis, had poor clinical trial results.

With investors losing confidence and becoming more reluctant to invest in risky stocks, companies have become discouraged about their ability to find capital to fund R&D (C&EN, Feb. 7, page 7). However, at several major companies where product sales contribute significantly to revenues, R&D spending increased in 1993. And overall, companies still did well in raising money sporadically through public and private financings in 1993.

Few biotechnology companies were profitable in 1993

$ Millions	1993 Revenues[a]	1993 Earnings	Change from 1992 Revenues	Change from 1992 Earnings	Profit margin[b] 1993	Profit margin[b] 1992
BIOPHARMACEUTICAL						
Affymax	$ 15.2	$ –20.3	19%	nm	def	def
Agouron Pharmaceuticals	12.8	–10.6	53	nm	def	def
Amgen	1,401.0	356.4	24	16%	25.4%	27.2%
Biogen	149.3	32.4	10	–15	21.7	28.4
Centocor	80.1	–74.4	–41	nm	def	def
Cephalon	18.7	–19.2	54	nm	def	def
Chiron	317.5	18.4	29	nm	5.8	def
Cytogen	12.3	–29.2	–28	nm	def	def
DNX	23.7	–19.4	218	nm	def	def
Genentech	649.7	58.9	19	183	9.1	3.8
Genetics Institute[c]	107.8	–16.9	23	nm	def	def
Gensia Pharmaceuticals	33.4	–63.3	–5	nm	def	def
Genzyme	280.1	–6.1	20	nm	def	def
Immune Response	9.1	–15.7	–18	nm	def	def
Immunex[d]	96.0	–361.7	nm	nm	def	def
Isis Pharmaceuticals	12.1	–19.1	12	nm	def	def
Liposome	13.0	–22.5	20	nm	def	def
MedImmune	16.8	–13.2	9	nm	def	def
Oncogene Science	16.6	–3.4	36	nm	def	def
Scios Nova	54.2	–36.6	70	nm	def	def
Synergen	23.5	–86.6	–54	nm	def	def
T Cell Sciences	10.7	–7.8	–19	nm	def	def
U.S. Bioscience	8.2	–40.6	–28	nm	def	def
Vertex Pharmaceuticals	29.3	2.0	409	nm	7.0	def
Vestar	35.1	–4.6	16	nm	def	10.3
Xoma	4.2	–31.3	–60	nm	def	def
AGRICULTURAL						
Biosys	9.6	–12.9	111	nm	def	def
Calgene	32.1	–35.7	24	nm	def	def
Crop Genetics	3.9	–8.5	–4	nm	def	def
DNA Plant Technology	10.3	–33.9	–14	nm	def	def
Ecogen	19.7	–11.9	119	nm	def	def
EcoScience[e]	5.9	–9.4	478	nm	def	def
Mycogen	123.9	–45.2	226	nm	def	def

a Includes product sales, contract research, royalty, and interest revenues for calendar year. b After-tax income as percentage of revenues. c Fiscal year ends Nov. 30. d For seven months from June 2 through Dec. 31, 1993, after merger with oncology business of Lederle Laboratories. e For year ending June 30. nm = not meaningful. def = deficit.

According to the Cambridge, Mass.-based consulting firm Feinstein Partners, biotechnology firms raised $2.8 billion in 1993. In comparison, $2.5 billion was raised in 1992, and $3.4 billion in 1991, the most lucrative financing year in the industry's history. Even though the amount raised in 1993 was close to that of earlier years, the average size of deals was down 30 to 40% from 1991 levels and a greater number of deals were financed privately.

The darkest months in 1993 were those leading up to the announcement of President Bill Clinton's health care proposal, says Peter Feinstein, president of Feinstein Partners. Like numerous other consultants, analysts, company executives, and industry representatives who spoke out during 1993 and in 1994, Feinstein underscores the negative effect that uncertainty about health care reform and the prospect of de facto drug price controls are having on the biotechnology industry.

Much of the industry's energy and that of its trade association, BIO (Biotechnology Industry Organization)—formed from the merger of two industry groups in 1993—has been focused on health care reform. Even so, companies have continued to produce important innovative therapies and products. Some of these new biopharmaceuticals, which brought the total up to 20 approved to date, are poised to make significant gains throughout 1994.

Two Factor VIII blood-clotting products for hemophilia were on the market by early 1993. In late July, β-interferon, for treating multiple sclerosis, was granted U.S. marketing approval (C&EN, Aug. 2, 1993, page 5). And Pulmozyme (DNase), an enzyme for treating cystic fibrosis, received U.S. marketing approval early in 1994 (C&EN, Jan. 10, page 5).

FDA's rapid review of both Pulmozyme and β-interferon in under one year has made the industry hopeful that other products might move through the regulatory process more quickly. At least five products, out of more than 140 reported to be in human clinical trials or awaiting approval, are anticipated to be close to market. Product reviews are expected to move even more quickly as FDA's Center for Biologics completes its reorganization and hires the added staff made possible by newly implemented user fees.

Leading the industry in product sales is Amgen; its 1993 revenues increased 24% from 1992 to $1.4 billion, and net earnings rose 16% to $356 million. But Genentech leads in the number of biotechnology products it sells—five—and in being responsible for another five, including Monsanto's bovine growth hormone, sold by licensees. The firm's 1993 revenues grew 19% to $650 million and earnings rose 183% to $59 million.

Biogen's fifth consecutive profitable year can be attributed to the royalty income it receives on major biopharmaceutical products that had sales of $1.5 billion in 1993. Revenues were up 10% to $149 million, but earnings dropped 15% to $32 million as the result of special one-time charges. The company hopes to bring its first two proprietary products to the U.S. market next year, which may increase expenses and again lead to mixed finanical results.

Genzyme is anticipating FDA approval of a recombinant form of Ceredase before midyear 1994. The company's nonrecombinant enzyme, used for treating Gaucher's disease, contributed about $124 million in sales to its $280 million in revenues in 1993. While revenues grew 20%, its reported loss was only $6 million.

For Chiron, the approval of β-interferon was a milestone as the first bio-

Biotech R&D spending levels are high

	R&D spending			
			As % of revenues	
$ Millions	1993	1992	1993	1992
Amgen	$255.3	$182.3	18%	16%
Biogen	79.3	60.4	53	45
Centocor	66.1	106.6	83	79
Chiron	140.0	142.3	44	58
Genentech	299.4	278.6	46	51
Genetics Institute	102.1	90.1	95	103
Gensia	54.3	40.4	163	115
Genzyme	48.3	39.7	17	17
Immunex[a]	49.7	37.1	52	52
Medimmune	14.9	11.3	89	73
Scios Nova	39.5	29.9	73	94
Synergen	88.3	60.3	376	117
Xoma	26.9	30.1	640	287

a 1993 figures for June 2 through Dec. 31, after merger with oncology business of Lederle Laboratories.

pharmaceutical product developed, rather than acquired, by the company. Sales are expected to grow substantially for the product, and the company is adding production capacity; capital spending reached $155 million in 1993 and is expected to continue at this level in 1994. Demand for β-interferon has been strong and the company hopes to produce enough for double the number of patients, up to 40,000, by the end of 1994, and more than 100,000 in 1995. Chiron reported a profit of $18 million on revenues of $318 million in 1993.

Factor VIII is bringing added royalty income to Genetics Institute, which had nearly break-even results in the fourth quarter of 1993. For the year, the company reported revenues of $108 million, up 23% from 1992, and a net loss of $17 million, down from a loss of $37 million in 1992.

The biggest losses in the industry were reported by Immunex and Synergen. A $346 million charge related to Immunex's merger with Lederle Laboratories' oncology business in early June contributed to a $362 million loss for the June through December period. Revenues for the same period in 1993 reached $96 million. Synergen's losses increased to $87 million in 1993, up from $41 million a year earlier, while revenues dropped 54% to $24 million, largely because of a decrease in R&D funding. In April 1993, the company moved to tighten its research focus and conserve resources.

Sales of major biotechnology products grew in 1993

		Sales ($ millions)	
Company	Products	1993	1992
Amgen	Erythropoietin Granulocyte colony-stimulating factor	$586.9 719.4	$506.4 544.6
Biogen[a]	α-, β-, and γ-Interferons; hepatitis B vaccines and diagnostics	136.4	121.7
Centocor	Antisepsis monoclonal antibody[b], diagnostic products	48.1	58.4
Chiron	β-Interferon[c] Interleukin-2 and other oncology products, ophthalmics	11.8 147.9	nm 111.6
Genentech	Human growth hormone Tissue plasminogen activator γ-Interferon Human insulin, α-interferon, and Factor VIII	216.8 236.3 4.3 112.9[d]	205.9 182.1 2.9 91.7[d]
Genetics Institute	Factor VIII[e] Erythropoietin, granulocyte macrophage colony-stimulating factor (GMCSF), Factor VIII	41.3 26.5[f]	nm 27.3[f]
Genzyme	Therapeutics, fine chemicals, diagnostics products and services	233.9[g]	180.0
Immunex[h]	Oncology products[i] Granulocyte macrophage colony-stimulating factor	46.7 42.1	nm 26.3

a Predominantly royalty income from $1.5 billion in sales by licensees. b European sales in 1992. Sales halted in January 1993. c Initial sales began in third-quarter 1993. d Royalties from licensees' sales. e Factor VIII approved for marketing December 1992; includes sales of product to marketing partner Baxter. f Royalties on overseas sales of erythropoietin and GMCSF, and on U.S. sales of Factor VIII. g Includes about $124 million in therapeutics sales of glucocerebrosidase. h Merged with oncology business of American Cyanamid's Lederle Laboratories in June 1993. i Sales of certain Lederle products between June 2 and Dec. 31, 1993. nm = not meaningful.

For the first time in a few years, Centocor did not lead the industry in red ink. Centocor cut its losses in 1993 to $74 million, down from losses of $105 million in 1992 and $196 million in 1991. Despite pulling Centoxin from the market, the company had revenues of $80 million, down 41%. Its cost-saving measures, put in place in 1993, have been having an effect. The company expects 1994 to be a "turnaround" year, and to make a profit in 1995.

The agricultural side of the biotechnology industry continues to operate at an overall loss. But several major events in 1993 could set the stage for future industry growth. For example, regulatory approval was granted for bovine growth hormone and sales began in February. In March, the U.S. Department of Agriculture came out with a new policy on field trials of genetically engineered plants.

Even though they lack profits as a group, agricultural biotechnology companies did register substantial growth in revenues in 1993. Both EcoScience and Biosys had large increases in revenues starting from very small base levels. Ecogen's more than 100% jump largely was due to contract revenues and biopesticide product sales that more than doubled to $7.2 million. Although its product sales grew, DNA Plant Technology's (DNAP) revenues dropped 14% to $10.3 million.

Increased expenses and acquisition of DuPont's interest in a joint venture contributed significantly to DNAP's $34 million loss. Calgene's loss of about $36 million, on revenues up 24% to $32 million, also stemmed from increased expenses as the company positions itself for the anticipated launch of its genetically engineered tomato and cotton in 1994.

Mycogen's revenues jumped 226% to $124 million with the full-year effect of its majority interest in Mycogen Plant Sciences (formerly Lubrizol's Agrigenetics business). Earlier this year Mycogen expanded its ownership from 51% to just over 80%. Special restructuring and technology acquisition charges of $38 million contributed to a loss of $45 million, up from $31 million in 1992. Mycogen Plant Sciences plans to test-market its first insect-resistant hybrid seed corn in the 1994 growing season, and the company expects to be profitable in 1994. ☐

Export outlook modest for green technologies

Long ago, when Lyndon Johnson was President, his Office of Science & Technology issued a visionary report, "Waste Management and Control," recommending that industry design processes that convert toxic chemicals to benign products from the word go. The study was barely noticed.

It has taken a generation of chemists and chemical engineers to absorb the idea and convince their bosses that pollution prevention, or green technology, is good for the world and might also make them money. The field is now hotly competitive and may become a weapon in improving the country's trade balance.

But not quite yet, indicates Congress' Office of Technology Assessment. OTA has just issued a report, "Industry, Technology, and the Environment: Competitive Challenges and Business Opportunities," that explores the competitiveness outlook for environmental technology. As the report notes, the $100 billion abatement and control technology market is doing very well, but the green technology field is still finding its way. At the same time, both could use a stronger export policy push from Washington.

Of more help are the two trade associations that have been formed in the field—the U.S. Environmental Business Council in Boston and the Environmental Technology Export Council in Washington, D.C.

Several bills have been introduced in Congress to spur the field. The National Academy of Sciences and the National Academy of Engineering have conducted studies and held symposia on the subject and more are planned. In addition, the National Science Foundation, in a program begun by the late Kenneth G. Hancock, then NSF's chemistry division director, sponsors innovative research in the field.

Nevertheless, OTA says, process industries still think pollution prevention technology carries low-return capital costs. Companies still have to be nudged by regulation to take the extra innovative leap into sustainable approaches. According to Wendell Fletcher, the veteran OTA staffer who managed the study, "Most U.S. programs are very small. And only a handful consider pollution prevention in conjunction with other manufacturing needs, including energy conservation, productivity, and quality improvements."

As for export figures, where they are reliable at all, they are minuscule for a field that appears to have such vast potential. Most activity is, again, in abatement, and seems to go on inside national borders. The Organization for Economic Cooperation & Development ranks Germany as export leader with a $10 billion surplus in 1992, the U.S. second with a $4 billion surplus, and Japan third with a surplus of $3 billion. The U.S. government, the report says, is far from establishing a set of coherent policies to spur the export effort. Still, the report continues, if such a commitment were seriously undertaken, it would in time pay off. Commerce Secretary Ronald H. Brown says the global environmental technology market could run as high as $600 billion by 2000.

The report was written from two specific market perspectives. One is that of the technologies that help companies comply with regulations—that is, technologies that treat or remove toxic emissions after they are produced. The other perspective is more exciting—technologies that catalytically turn toxic chemicals into benign entities in the production process itself, or don't produce any at all.

The former approach is "old-think," according to Fletcher. The new way to go is clearly in the direction of pollution prevention. "There is significant potential in pollution control technology," he says. "It is more cost-effective and would clearly make it easier for manufacturing firms to comply with environmental requirements. We see a shift toward what we call cleaner technologies."

Fletcher says, however, that people shouldn't expect much of a domestic job bonanza to accompany most of the technologies. The U.S. may export a lot of know-how abroad. But much of the construction will probably be done using local labor, materials, and parts. "Many of the jobs in this country," he says, "will be high-wage technical or engineering jobs." Another inhibiting factor in the U.S. export outlook, according to the report, is that most green technology firms are small or medium sized and have little export experience.

Several policy approaches are needed to give the field the nudges it needs, and there are many. First, it would help if all of the countries of the world adopted uniform environmental quality standards.

But more important, the right export infrastructure is still lacking in the U.S. Both Japan and Europe offer their firms much more export assistance than does the U.S. government. Moreover, the report adds, more assistance by various lending institutions is needed to help developing countries get better information about these new technologies.

Another approach would be for U.S. regulators to give top-level "environmental performers" more choice in the technologies they use. Yet another would be to integrate environmental objectives into the support the U.S. government already gives to manufacturing technologies. The report lists 33 options in all.

Wil Lepkowski

Estimates of global market size for environmental technologies vary, but U.S. is viewed as strongest competitor

	Organization for Economic Cooperation & Development (OECD)			Environmental Business International		
	Market size			Market size		
$ Billions	1990	2000	Trade balance[a] 1990	1992	1997	Product exports 1992
U.S.	$ 78	$113	$ 4	$134	$180	$ 7
Western Europe	54	78	8	94	132	na
Germany[b]	17	23	10	36	na	11
Japan	24	39	3	21	31	5
Other OECD countries	9	15	na	13	22	na
Eastern Europe/ former U.S.S.R.	15	21	na	14	27	na
Other non-OECD countries	21	34	na	19	34	na
WORLD TOTAL	$200	$300		$295	$426	

[a] Includes goods, services, and licenses. [b] Germany's share of Western Europe. The OECD estimate is for western Germany; about half of this number is exports. na = Data not available or separately listed. **Source:** Office of Technology Assessment

PRODUCT REPORT

PERSONAL CARE PRODUCTS

Demand for more creative ingredients rejuvenates an aging market

Susan J. Ainsworth, C&EN Houston

The cosmetics and toiletries market—which includes myriad products from makeup and hair preparations to fragrances and dentifrices—has long been regarded as recession-proof. In other words, when the economy starts to slip, consumers may stop buying new cars, but they don't stop washing their hair.

Demand for products in the mature cosmetics and toiletries market has been slow and steady throughout the past several years as the recession has gripped U.S. businesses. In 1993, industry shipments increased more than 4% to $18.8 billion, or 2% in constant dollars, the same rate of increase as in 1992. And the same growth is forecast for 1994, according to the Department of Commerce's U.S. Industrial Outlook report on cleaning preparations and cosmetics, released early this year.

Although companies that formulate and market cosmetics and toiletries may be ringing up sales at a constant pace, the slow economy has influenced the industry in other ways. During a recession, consumers look for value by buying more multifunctional products, such as shampoos that clean, condition, and add shine. They want products that will provide a proven benefit. Consumers also typically trade down to lower priced products. Consequently, the sluggish economy has adversely affected the industry's luxury and designer segment, the Commerce report points out. At the same time, recession-driven downsizing programs and consolidations have trimmed back the human resources so crucial to cosmetics and toiletry companies.

As these leaner cosmetics and toiletries companies experience added pressure to provide more value to the consumer, they have been turning increasingly to their raw material suppliers for support. "Throughout the 1990s, as our customer [firms] continue to streamline their organizations, they have placed greater importance on the supplier to assist in new product development and product improvement through both new materials and technical support," says Salvatore J. Guccione, vice president and business director for personal care products at International Specialty Products, Wayne, N.J.

Companies that formulate and market cosmetics and toiletries are demanding better performing, more creative ingredients at lower cost. "Recognizing that the consumer isn't going to pay high prices for something new and fancy, the marketplace wants the best technology at the lowest possible cost," says James F. Manier, business director for personal care products at Cranbury, N.J.-based Rhône-Poulenc's surfactants and specialties business unit.

From the point of view of the raw material supplier, the cosmetics and toiletries market "may be recession-proof in terms of [sales] volume, but not in terms of pricing or profitability," says Tom O'Brien, manager of surfactants sales in Vista Chemical's surfactants and specialties division in Houston.

This recession-driven pressure on raw material suppliers is not abating. They say they are only just beginning to feel the recovery that economists have been proclaiming.

In today's economy, suppliers have to be creative to meet formulators' cost and performance challenges and still remain competitive, says Frank J. Freiler, director of marketing for Union Carbide's Amerchol subsidiary, an Edison, N.J.-based specialty chemicals company serving the personal care and cosmetics industry. These challenges can "create opportunities for suppliers who are willing to go the extra yard in support of customers' needs."

In addition to providing cost-effective formulation solutions, suppliers can gain an edge in the marketplace by help-

National Starch researchers evaluate variety of personal care products.

ing their formulator customers develop more environmentally friendly products. Marketers are rethinking entire production lines in response to continuing consumer demands for clear and natural products that contain no animal by-products and are not tested on animals.

Likewise, raw material suppliers can capture additional growth by developing ingredients consistent with the changing demographics in the U.S. As the population ages, the demand for cosmetics with milder formulations, softer colors, and treatments for aging skin increases.

Indeed, suppliers of ingredients have had to be more innovative and industrious than ever to survive in today's intensely competitive marketplace. They have had to endure poor profitability over the past few years, says Larry Moss, vice president for household, personal care, and industrial products in Witco's oleosurfactants group, New York City. Customer companies have been demanding lower ingredient prices while "our raw material costs remained unchanged," Moss says. O'Brien adds, "Margins have suffered due to the poor economy and overbuilding of capacity around the world—and that's a real problem."

However, ingredient suppliers are beginning to sense an upturn in the economy. And they are hopeful that during the course of 1994 they will be able to "initiate the price increases that have been necessary for well over a year," says Moss. "We can't continue to absorb all of the costs by ourselves."

Suppliers to the cosmetics and toiletries industry are "guardedly optimistic" that recovery is on the way, says Janet C. Kosiek, product manager for specialty surfactants in the performance products division of Lonza, Fair Lawn, N.J. "Things seem to have stabilized somewhat, and I get the feeling that marketers are not operating in such a frenzy."

Moss says he senses that customer formulators are a little bit busier and "not down in the doldrums as much." However, improvements in the economy and in the business are still touch and go.

Rhône-Poulenc's Manier adds: "You might go for three months doing just great and then all of a sudden it is the end of the next month and you wonder what has happened."

New product introductions, an important yardstick for measuring the extent of the recovery in the cosmetics and toiletries market, seem to be on the rise again. "Companies are apprehensive about introducing new concepts at any time, owing to the risk involved," says Judith Grey, director of marketing for Haarmann & Reimer's fragrance division, referring to the millions of dollars marketers must invest in advertising to launch a new product. "Certainly, in tight economic times this apprehension increases," she points out. However, Springfield, N.J.-based Haarmann & Reimer was among many companies that experienced an increase in the number of new products being introduced and developed in 1993.

"And this is expected to continue into the near term," says Amerchol's Freiler. As cosmetics and toiletries companies launch more new products, more demand for innovative chemistries and ingredients is created, which, in turn, generates opportunities for raw material suppliers.

Synergy and ingredients

To be sure, suppliers see opportunities in developing new raw materials that continue to give more bang for the buck. "Functionality is a macrotrend around the industry," says Freiler. "Products need to do more, and in some instances cost less. This is the value-oriented market approach that is based on products meeting, and not exceeding, the needs of the consumer at a lower price."

With the cost pressures that ingredi-

U.S. raw material suppliers look to developing nations for growth

As the Cosmetic, Toiletry & Fragrance Association, Washington, D.C., celebrates its centennial anniversary this year, it serves as one more reminder that the U.S. personal care industry is well into its mature years. Although changes in the cosmetics and toiletries market continue to create new niche opportunities, overall demand for cosmetics and toiletries generally tracks gross domestic product growth.

Therefore, it's no surprise that U.S. cosmetics and toiletries producers and their raw material suppliers are increasingly looking beyond the nation's borders. "The cosmetics industry is recognizing that globalization and meeting the differing demands of consumers around the world are the keys to competitiveness in the marketplace," according to the Department of Commerce's U.S. Industrial Outlook report on cleaning preparations and cosmetics, released early this year. "Cosmetics and toiletry companies and their suppliers are becoming increasingly global through constant acquisition, consolidation, and reorganization," the report says. "Corporate investment strategy, advertising, and R&D are shifting from an emphasis on domestic markets to international markets."

Long-term prospects for exports of U.S. products look most promising in Latin America and the Asia-Pacific region, especially China and Japan. The Commonwealth of Independent States (the former Soviet Union) and Eastern Europe also offer opportunities for trade expansion. However, these opportunities will be limited over the near term because of lack of hard currency, the report adds.

Raw material producers point out that even in Latin America and the Asia-Pacific region, market opportunities are limited for now. "Short term, growth has been below expectations and it's anybody's guess as to when the markets will pick up," says Tom O'Brien, manager of surfactants sales in Vista Chemical's surfactants and specialties division, Houston. "People in developing nations are still worrying about eating and cleaning their clothes so, understandably, personal care products are not yet a high priority," he says.

Slow or declining growth in demand for personal care products has been responsible for delivering disappointing returns for companies investing in developing nations. In addition, it has contributed to an oversupply problem for certain raw materials, such as linear alcohols. Additional product produced in anticipation of demand growth in developing nations is now being shipped to developed nations, creating a glut of some products, says O'Brien.

Still, companies investing in developing nations now are going to have a long-term advantage, O'Brien concedes. They will be firmly established long before some of their competition when growth begins to climb.

Indeed, forward-thinking U.S. companies are laying claims to international markets both by increasing exports to those regions and by setting up or expanding operations there. According to the Commerce report, exports of personal care products from the U.S. grew 14%

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ent suppliers have been enduring for several years, it has been difficult for them to offer less expensive products. Therefore, suppliers have been looking at how they might put raw materials together to create certain synergies in formulations, says Witco's Moss. "They want to know if one and one can equal three instead of two," he explains.

For example, along with an alkanolamide, which is traditionally added to build viscosity and foam, Witco might add a betaine, which gives a formulation the mildness that is so much in demand right now in personal care products. Even while the less expensive alkanolamide does the majority of foam and viscosity building, "a little bit of betaine allows a company to claim it has a low-irritation formulation," says Moss. "Plus, because most of our betaines are made from vegetable-based sources, their addition to a product might allow customers to tout a product as natural."

In an effort to cash in on this trend, in February Rhône-Poulenc launched its Miranol Ultra C-32, an amphoteric surfactant for personal care products that enhances the performance of other surfactants in a formulation, Manier says. For example, "a customer might be able to substantially reduce or eliminate other key traditional ingredients (such as hydrotropes) with the addition of Miranol Ultra, which enhances the detergency, foaming, and mildness of a formulation."

Based on a patent-pending technology, Miranol Ultra can be used to create products with a higher actives-to-solids ratio, reducing the by-product profile, according to Michael L. Finney, director of commercial development for Rhône-Poulenc's surfactants and specialties business unit. Most amphoterics now on the market, such as glycinate, have an actives-to-solids ratio of about 60%, whereas these new products have a ratio of more than 80%. The high actives-to-solids ratio leads to reduced viscosity, which makes the product easier to pump and handle in manufacturing. This allows customers to formulate products with higher levels of active ingredients while offering superior consistency and stability. More cost-effective formulations likely will be much easier to attain with this new product, adds Finney.

In the area of ingredient synergies, Witco is doing more application work and some basic R&D at both its Chicago and Dublin, Ohio, personal care laboratories, says Moss. "In addition, we are working closely with our European surfactant groups in this area. This will allow us to keep up with the latest trends in Europe, which tend to eventually show up in the U.S."

Witco has stepped up its application work not just in ingredient synergies, but across the board, says Moss. "Customers are not in a position to do as much [of this work] as they used to," especially after major downsizing programs. "They need to get products out onto the shelves faster and so they are depending on their raw material suppliers to give them more support."

In addition, the cosmetics and toiletries companies want proof, in the form of product information, that the ingredients they are buying meet their needs. It is increasingly critical in the new product process for a supplier to be able to tell a formulator what its new ingredient can do that "one of the 6,000 ingredients" currently available does not, says Freiler.

Today, resource-short marketers have to lean more on suppliers. Estée Lauder, New York City, for example, recently turned to Hopkinton, Mass.-based Zylast year, accounting for roughly 7% of total product shipments.

Eager to tap growth in developing nations, just last year National Starch established regional technical centers in Singapore and Brazil to service the Southeast Asian and South American markets, respectively, says John Mooney, the company's business director for specialty polymers.

International Specialty Products, Wayne, N.J., maintains sales representation covering every major market in the world, notes Salvatore J. Guccione, the company's vice president and business director for personal care products. Supporting those sales are three labs in the U.S., two in Europe, and one in Singapore. The company "is well positioned to capitalize on growth in the Asia-Pacific market" because it has been opening sales offices there over the past 10 to 15 years, he adds. International Specialty Products also plans to open new sales offices in China, Vietnam, Indonesia, and India sometime in the future. For Latin America and South America, the company maintains direct sales representation in Mexico, Argentina, Brazil, and Venezuela; it has also just opened a personal care technical service lab in Brazil. "This structure allows International Specialty Products to participate effectively in the regions of anticipated growth."

Similarly, Vista Chemical maintains a sales force in Latin America, a sales office in Singapore, and an office with sister company Condea in Tokyo. In addition, last summer Vista licensed technology to the Chinese government for the construction of a 100,000-ton-per-year α-alcohols plant at Jilin City in northeastern China. All of the plant's production will be consumed within China to make personal care and other products. Vista is not a joint-venture partner in the plant, but O'Brien says it is "evaluating further business opportunities" at Jilin.

Witco, too, is expanding its participation in developing countries. One objective of a companywide restructuring program completed last year was "to better define how we will expand and develop on a global basis," says Larry Moss, vice president for household, personal care, and industrial products within Witco's oleosurfactants group, New York City. The company has established sales offices in Sao Paulo, Brazil, and New York City to handle South American and Latin American markets. In the Asia-Pacific market, Witco has set up a sales office in Singapore, "where we expect to have manufacturing capabilities within the next 18 to 24 months."

Multinational company Lonza is another raw material producer that has set up a string of distributors and agents throughout Latin America and the Asia-Pacific markets, says Janet C. Kosiek, product manager for specialty surfactants in the performance products division of Lonza, Fair Lawn, N.J. "As the cosmetics and toiletries business becomes more global, there will be less emphasis on regional purchases and more focus on the growing markets around the world." Simply put, she says, "You will have to be able to compete in those markets because if you just want to compete in your own country, you are going to be left out."

mark Corp., a leader in the field of laboratory automation. Estée Lauder needed a robotic system that could perform preservative challenge tests to determine the efficacy of preservatives used in cosmetic formulations. Testing preservatives requires that large volumes of samples be analyzed repeatedly under the same conditions, making it a highly labor-intensive and repetitive task that consumes many employee hours, says Steve Schnittger, a group leader at Estée Lauder's Melville, N.Y., laboratory. The automated robotic system can effectively perform this function, "freeing up the microbiologist to perform more creative tasks."

Formulators have no choice but to be more trusting of the quality and performance data that their suppliers provide with their raw materials, opting to skip tests that would check such information. This allows formulators to focus on their primary goal: selling their finished products, Moss adds.

Indeed, raw material suppliers say they are doing more for their formulator customers today than ever before. For example, Hüls America in Piscataway, N.J., "has focused more of our activity on service, ranging from responsive application assistance to adjusting inventories to meet just-in-time delivery requirements," says Barbara Pagliocca, the company's marketing and sales manager for personal care products.

To better meet formulators' changing demands, International Specialty Products has created market-focused business units. In addition, in 1993 the firm's personal care business unit—which handles hair care resins, preservatives, ultraviolet absorbers for sunscreens, pearlescent pigments, emollients, and emulsifiers—expanded its R&D and technical service departments.

Clearly, suppliers today must focus on making things as easy as possible for their customers who formulate and market cosmetics and toiletries.

Convenience of blends

In keeping with this trend, raw material suppliers say they are selling more convenience products such as finished blends and concentrates. With one of these products in hand, a formulator might need only to make an adjustment in the viscosity and add color and fragrance to arrive at a ready-for-market formulation, says Moss.

"Proprietary blends" that are tailored for a particular company are now becoming more popular. Many times formulators will define what they want in a blend and the cost they are willing to pay before they deal with their suppliers, Lonza's Kosiek adds. Formulators may use one of these proprietary blends as the basis for multiple product lines.

Blends also bring cost savings. When relying on finished blends, these companies don't have to maintain big, expensive inventories of chemicals; they don't have to worry about the inherent costs in making a bad batch; and they can dispense with quality checks on long lists of ingredients. Furthermore, they can operate with fewer employees and they don't have to make a big investment in "pots and pans," says Moss.

Also, blends allow formulators to gain economies of scale, adds Lonza's Kosiek. For example, formulators might get to a finished product simply by diluting a blend rather than combining six ingredients. Therefore, companies can increase their rate of processing and their capacity without investing in additional equipment. In addition, blends often bring together many different functionalities in a single formulation, an attractive trait to marketers who are trying to

Anionics are most widely used surfactants in personal care products

Millions of lb	Consumption				% annual change	
	1982	1987	1992	1997	1982–92	1992–97
Anionics	229	335	455	525	7.1%	2.9%
Nonionics	35	47	60	80	5.5	5.9
Cationics	35	50	65	80	6.4	4.2
Amphoterics	13	18	26	35	7.2	6.1
TOTAL	**312**	**450**	**606**	**720**	**6.9%**	**3.5%**

Note: Excludes surfactants used in soaps. **Source:** Freedonia Group

satisfy consumers with multifunctional products.

The proliferation of multifunctional products such as shampoo-and-conditioner combinations is also creating opportunities for surfactant manufacturers. Frequently, combination products compromise the qualities of the various components by interacting adversely with other ingredients, says a 1993 report on surfactants by the Cleveland-based consulting firm Freedonia Group. Demand is up for surfactants that are compatible with other materials and that can enhance product effectiveness.

Two-in-one products are increasingly incorporating amphoteric surfactants—like Lonza's Amphoterge K2—that are compatible with anionic, nonionic, and cationic surfactants, says Kosiek. Amphoterics can help to solubilize cationic conditioning agents so that they are more easily incorporated into an anionic shampoo system, she adds.

'Cosmeceuticals' take hold

Just as consumers are driving the trend toward multifunctional ingredients, they are also creating demand for products with demonstrable benefits. "More than ever, cosmetic raw materials are being evaluated by what they can do to provide not only a good look but also some type of health benefit," says Gary Romans, director of marketing for the aroma chemicals division of Haarmann & Reimer.

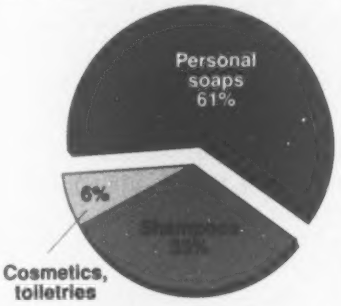
Three market forces seem to be driving the trend toward products that medicate as well as beautify. For one, more educated consumers are demanding products based on sound science, says the Commerce Department report. Second, the average age of consumers is rising, creating demand for more therapeutic products to care for older skin. And third, the recession may also have fueled demand for these types of products.

"Before the recession," says Lonza's Kosiek, "people had enough discretionary income to allow them to buy and try six or seven products before they found one they liked. Now, I think people want to be sure that the single product they purchase is going to work for them." The Commerce report expects that, despite predicted recovery in the economy, this trend will continue into 1994 "as cosmetics become 'cosmeceuticals.' "

Developing such products creates challenges for raw material suppliers and formulators alike, but the investment may be worth it. For instance, using science to create new products has paid off for the sunscreen market, which now has annual U.S. sales exceeding $500 million, the Commerce report points out. Similarly, sales of therapeutic skin care products, such as those containing vitamins, free-radical scavengers, and especially α-hydroxy acids, have skyrocketed.

Hair care marketer Zotos, Darien, Conn., has responded to the demand for more scientifically based products. This past summer the firm introduced its patented Senscience line of hair care products that contain an inner cellular membrane complex that mimics hair's own cell membrane to restore strength and body, says Thomas M. Schultz, Zotos' vice president of research and development.

Most personal care surfactants used in soaps



Projected 1997 consumption = 1.83 billion lb

Source: Freedonia Group

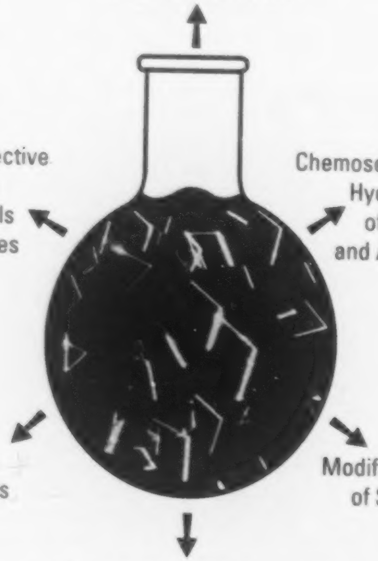
Over the past few years, cosmetics companies have begun using fruit acids (organic acids including citric acid, malic acid, lactic acid, and glycolic acid) to formulate a bevy of new products such as Avon's Anew moisturizer. In the proper concentrations, fruit acids exfoliate dead skin cells leaving skin smoother and tighter with a more youthful appearance, says Mark P. Conlon, marketing manager for Haarmann & Reimer's food ingredients division in Elkhart, Ind. Cosmetics formulators also report that fruit acid treatments result in a reduction of liver and sun spots as well as diminution of wrinkles.

Natural products

Another advantage that α-hydroxy acids bring to cosmetics and toiletries companies is that they are perceived as natural by the consuming public. That's important as consumers become more concerned about synthetic and animal-derived products. For example, glycolic acid is touted as natural to sugarcane and sugar beet; lactic acid is claimed to be natural to sour milk; citric acid is said to be natural to fruits and vegetables and most living organisms; and malic acid is natural to apples and grapes.

In reality, commercial glycolic acid is produced as an intermediary in the manufacture of ethylene glycol through the reaction of formaldehyde with carbon monoxide. Malic acid is derived from the reaction of maleic anhydride with water. Only citric acid and lactic acid are produced from natural fermentation processes generally utilizing corn or sugar substrates. According to Conlon, Haarmann & Reimer is the leading global producer of citric acid and malic acid grades that are used as the acid basis for personal care products.

The cosmetics and toiletries industry often takes liberties with the term natural because products with this label can be sold at a premium price. However, not all products labeled as natural contain an extract, such as aloe, in a minimally processed form. A coconut-oil-derived surfactant may be deemed natural even though it is just as highly processed as a "synthetic" ingredient derived from petrochemical sources. The issue should not be whether an ingredient is based on a renewable resource, say many companies. Instead, the cosmetics and toiletries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industry has begun to focus on how the ingredient affects the environment as it is processed, used, and discarded.

Life-cycle analysis

Although many raw material suppliers support the life-cycle analysis concept in theory and would gladly dispense with the oversimplified use of the terms natural and synthetic, they also point out that providing a complete life-cycle analysis for an ingredient may not be practical. Developing a full environmental impact profile for an ingredient would take years and a great deal of capital, says Witco's Moss. It requires retracing the processing of an ingredient, noting such details as to even how water was processed at a particular step in a raw material production process. What's more, suppliers don't always have control over factors that affect a product's life cycle, he says. "If customers wanted to have a life-cycle analysis profile of everything that they bought, they would not be buying very much."

Marketers may not yet be sure about what constitutes a natural or environmentally friendly product, but they are sure about one thing: They can sell their products much more quickly if they can put the word natural on their labels. For example, Blaine, Minn.-based Aveda has built its entire personal care product portfolio around "pure flower and plant essences and other natural elements" with much success. This month, Aveda is launching a new lip color based on a plant pigment harvested from uruku trees growing in the Brazilian rain forest. Aveda says its products are not tested on animals and contain very few animal by-products.

The naturals movement has been a boon to raw material producers who are able to sell ingredients that are perceived as natural. Pagliocca of Hüls America says: "We have experienced above average growth over the past several years, particularly for our coconut-oil-derived products, as a result of the current industry trends" and the growth potential for these products is expected to remain high.

Similarly, Henkel reports increased customer interest in its Plantaren alkyl polyglycoside surfactants, which are made from glucose derived from corn and fatty alcohols derived from coconut and palm-kernel oils. These surfactants are used in a wide variety of products from facial cleansers to bath products to shampoos. In addition, growing demand for natural products prompted the company to introduce its Gluadin almond protein hydrolysate, which is derived from enzymatically degraded almond flour and is used to improve moisturization, product feel, and mildness in personal care products.

Renewed interest in the use of all-natural ingredients is one factor spurring growth in sales of waxes. Demand for waxes used in cosmetics and toiletries applications is expected to grow 6.7% per year to $180 million in 1997, according to another Freedonia report on natural and synthetic waxes. Cosmetics have historically included natural waxes in a variety of products ranging from lipsticks and makeup preparations to creams and lotions based on emulsions.

As formulators and marketers add more plant-derived ingredients to their products in an attempt to profit from the naturals trend, they are also benefiting from sales of products that consumers sense to be "greener." For example, in the past year consumers have gravitated toward clear products simply because they perceive them to be more natural, when, in fact, they generally are formulated no differently than their colored counterparts. In 1993, the industry has introduced clear deodorants, hair gels, face cleansers, and mouth washes, for example.

Picking up on this trend, in June last year PPG Specialty Chemicals, Gurnee, Ill., a subsidiary of PPG Industries, introduced a highly water-soluble surfactant from which clear liquid products can be readily formulated. The product, an ammonium cocoyl isethionate, has many of the same performance properties as PPG's sodium cocoyl isethionate, including mildness, high foaming, lubricious lather, and soft skin.

Likewise, Lonza is using its light-colored Amphoterge amphoteric surfactant as a stepping stone into the clear hair care products market. "It is also easier to formulate a blue shampoo, for instance, if you start with a light-colored product as opposed to something with a yellow tint that tends to give you a green finished product," Kosiek says.

Changing the fragrance of products so that they smell more environmentally friendly is another way formulators have capitalized on the green movement. For example, marketers of skin care products are replacing traditional citrus and flower scents with herbal scents to satisfy changing consumer tastes while maintaining all-natural formulations, according to yet another Freedonia report on flavors and fragrances. For this reason, demand for fragrances used just in the skin care segment will grow faster than demand for fragrances used in all cosmetics and toiletries, which is expected to increase 9.2% annually to $885 million in 1997, according to the report.

Longevity of natural craze

Although raw material suppliers agree that natural is a buzzword in cosmetics now, they are divided in their opinions about its longevity. "Judging from the number of phone calls that we have received from customers asking about the origin of our raw materials, I think that the natural trend will continue for a while," says Patricia A. Mayer, marketing manager for Henkel's Cospha division, Ambler, Pa.

ISP manager uses "rotovat" to remove low boiling liquids and recover solids in cosmetics testing.

However, Vista's O'Brien believes that the trend will die down in the cosmetics market over time, especially when feedstock economics dictate such a shift to synthetic raw materials. "For example," he says, "today there's an oversupply of both oleochemical-based and petrochemical-based alcohols, so suppliers are working hard to try to sell their respective products. And if customers can get both at an equal price, today they may lean toward the one they can call natural, because it allows them to charge more or to avoid the whole natural-versus-synthetic issue."

But improvement in the economy and increased demand for all alcohols will trigger a shortage of one or the other, and then natural versus synthetic will become a nonissue, he says. "Marketers like to sell their products at a premium, but they are not going to pay a premium for their raw materials."

Natural raw materials may eventually fall out of favor because some—particularly botanicals—are more difficult to work with than synthetics. For starters, natural ingredients are many times less uniform and pure than a synthetic counterpart, points out Dante J. Rutstrom, principal technical representative for formulation products at Eastman Chemical in Kingsport, Tenn. Botanicals, for instance, vary in composition because of seasonal and geographic factors, sometimes producing inconsistent lots, which is a problem for cosmetics formulators.

Natural ingredients are also threatened by microbial contamination as they are collected, extracted, purified and stored—a problem that does not occur with synthetics, which can be processed aseptically. In fact, animal, mineral, and botanical ingredients serve as nutrients for different microbial strains.

In addition, natural ingredients are more likely than synthetics to cancel out or clash with other ingredients in a formulation. For example, α-hydroxy acids require lower pH levels to function in a formulation. Although Henkel does not supply fruit acids, it has been "actively working with customers to help them formulate around these requirements," says Mayer.

In skin care, some natural fragrance ingredients must be separated from other components to avoid adverse ingredient interactions, according to the Freedonia flavors and fragrances report. As a result, microencapsulated fragrances are increasing their presence in the market.

Recognizing the limitations of formulating with natural ingredients, Hüls says it has done the testing necessary to show that its naturally derived fatty acid esters, which are being used more and more in both skin care and decorative cosmetics, are fully compatible with the other currently popular ingredients, such as α-hydroxy acids, botanicals, and extracts. Likewise, Henkel says naturally derived surfactants such

Perfumes and colognes consume most flavors, fragrances used in cosmetics

	Consumption				% annual change	
$ Millions	1982	1987	1992	1997	1982–92	1992–97
Perfumes and colognes	$134	$271	$366	$555	10.6%	8.7%
Skin care products	52	104	148	240	11.0	10.2
Other	20	37	57	90	11.0	9.6
TOTAL	$206	$412	$571	$885	10.7%	9.2%

Source: Freedonia Group

as its Plantaren line are made to exacting standards and, unlike botanicals, are easy to work with and generally compatible with other ingredients in formulations.

Natural waxes are sometimes incompatible with modern cosmetic ingredients, including short-chain esters and silicone, according to Freedonia. As a result, manufacturers are working to develop synthetic products that meet the needs of cosmetics formulators and address the problems associated with natural products. For example, Croda has developed a line of synthetic waxes based on fatty acids that can be used in cosmetics. These products allow formulators to avoid variances in quality, availability, and price while providing key performance characteristics.

Milder products

Consumers are also more likely to experience an allergic reaction to natural ingredients. This can be a real drawback for marketers because consumers are increasingly demanding milder formulations. Growth in the nation's elderly population and a growing consumer awareness of skin disorders are two major factors spurring popularity of milder products.

This trend has also sent raw material suppliers back to their research labs to develop gentler ingredients, such as nonirritating surfactants, suitable for this growing market. Some of the milder specialty surfactants used in toilet soaps include those based on fatty isethionates, lauryl ether sulfates, sulfosuccinate fatty acids, and sodium cocoyl isethionate.

Recognizing the growing demand for mild cleansing surfactants, late last year Rhône-Poulenc expanded production of sodium cocoyl isethionate at its Winder, Ga., plant. In addition, "we are working on development of lauryl phosphates, which are extremely mild and high-foaming ingredients used in the formulation of facial cleansers," says Manier. Although phosphates are a concern in the laundry detergents market where they have a reputation for encouraging eutrophication of lakes and streams, these specialty phosphates do not cause the same problem because they do not produce high levels of free phosphate in solution as do household laundry detergents, he says. In addition, the specialty phosphates are used at much lower levels in personal care products than in laundry formulations, he points out.

Demand for surfactants used in shampoos, cosmetics, and toiletries is forecast to increase 3.5% annually to 720 million lb in 1997. However, sales of surfactants that can help satisfy continuing demand for improved natural-based and milder formulations will grow faster than average, according to Freedonia's surfactants report.

In the shampoo market, marketers have been changing formulations to improve mildness as well as impart a "luxury" feel to the hair, Freedonia says. As a result, anionic lauryl ether sulfates and other surfactants have begun to displace other anionics, such as alcohol sulfates, which have traditionally dominated the shampoo market. The most dynamic growth, however, has been in specialized cationics and amphoterics, such as imidazolines, betaines, and betaine derivatives.

The move toward milder shampoos has been good news for Vista Chemical, which is now making a concerted effort to expand its business in the cosmetics and personal care market. Because the company's Novel II narrow-range linear alcohol ethoxylates are milder than the industry's conventional alcohol ethoxylate counterparts, more customers are using them in their shampoo formulations, O'Brien says. The mildness trend has also supported demand for a line of Guerbet alcohols, esters, and other derivatives that Vista introduced this past January. The high-purity C_{12}–C_{14} alcohols are used to meet oily-component requirements in cosmetics, personal care products, and other end uses, says Jordan Layer, national marketing coordinator for cosmetics and specialties at Vista.

Expanding on the mild luxury product theme, body shampoos are attempting to break into the U.S. market after much success in Europe. After completing some test marketing early this year, Andrew Jergens Co. in Cincinnati has launched its Jergens Refreshing Body Shampoo, a new nonsoap liquid cleansing system. The product,

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which comes with a unique sponge, is intended to be a replacement for bar soap used daily in the shower or bath. "Test market results were very encouraging," says Tim Zimmerman, senior vice president of marketing at Jergens. The launch will be supported with a $50 million consumer and trade marketing plan that began last month.

In addition, a month ago Procter & Gamble began test marketing its body shampoo, Oil of Olay Moisturizing Body Wash, in Spokane, Wash. The body shampoo holds promise for marketers that are looking for a new marketing concept for 1994 "and we are ready to help manufacturers develop these formulations," says Henkel's Mayer.

It may create some opportunities for raw material suppliers, too. For example, Jergens' body shampoo is based on Rhône-Poulenc's new Miranol Ultra C-32 product. In response to growing demand for the amphoteric surfactant, the company last year boosted capacity for the ingredient at both its Dayton, N.J., and Mississauga, Ontario, Canada, plants. Henkel already is active in the body shampoo market; at least one of its customers has launched such a product formulated with Henkel's Plantaren surfactant.

In addition to seeking improved mildness, formulators will continue to demand greater functionality, higher value, and more detailed product information to back up those claims, says Freiler. In today's high-cost environment, performance data are increasingly critical to formulators who cannot afford to have unsuccessful product introductions. "In the future," Freiler adds, "fewer raw materials may make it to market, but those that do will have a greater reason for existing and an excellent chance of success."

Regulatory concerns

In addition to pleasing consumers by providing products that are economical, environmentally friendly, mild, and tailored to the changing demographics of the U.S. population, the cosmetics and toiletries industry must also address its share of legislative concerns.

Despite being largely self-regulating, the industry has been watching the Food & Drug Administration (FDA) more closely than ever over the past year. After surviving the transition to the Clinton Administration, FDA Commissioner David A. Kessler "is now free to take

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action that would never have survived scrutiny in the Bush Administration," says Peter Barton Hutt, outside counsel at the firm of Covington & Burling for the Cosmetic, Toiletry & Fragrance Association (CTFA), the 100-year-old trade group representing almost 500 cosmetics and toiletries marketers and raw material suppliers.

For example, the agency has more strictly enforced compliance to good manufacturing practices, shutting down some plants entirely, adds Hutt. "FDA's increased focus on implementing over-the-counter drug review represents a major regulatory threat for the cosmetics industry."

CTFA has been successful so far in fighting legislation that would give FDA more power over the cosmetics industry. Congress has been considering legislation that would dramatically increase FDA's inspection and enforcement powers. "Fortunately, that bill went nowhere last year," says Michael J. Petrina, CTFA's vice president of legislative relations.

CTFA also worked hard last summer to defeat a proposal that aimed to establish user fees on all FDA-regulated industries. "This would require our companies to register their facilities and products with FDA and pay annual registration fees to boot," Petrina says. Although the FDA enforcement bill is likely to remain dead for this year, the Administration is going to continue to push for user fees in the future, especially in light of FDA's budget problems, he predicts.

In 1994, the cosmetics industry will be paying particular attention to FDA's stance on the distinction between cosmetics and drugs. Responding to consumer demands, cosmetics and toiletries producers are turning out more efficacious products that sometimes straddle the line dividing cosmetics and drugs. As a result, FDA has begun to monitor these products more closely, focusing particularly on three areas: sunscreen products, dental products, and products containing hormone ingredients.

After 15 years of relative inactivity in the area, FDA issued a 100-page proposal on sunscreens, suggesting that they should be regulated as any other over-the-counter drug. In its current form, the proposal will target products used at the beach as well as traditional cosmetics products—skin care, color, and hair care products—that now contain sunscreen ingredients.

Meanwhile, FDA's Dental Products Panel is looking at whether antiplaque products should be considered drugs or remain categorized as cosmetics. Separately, this past September, FDA proposed that products containing hormone ingredients above a certain level are drugs, regardless of the claims made for the product. CTFA is actively working to provide evidence showing that these products should remain under the self-regulated classification of cosmetics.

CTFA survived another close encounter with FDA concerning hair dyes. Responding to media reports questioning the safety of hair dyes, last year Rep. Ron Wyden (D.-Ore.) asked the General Accounting Office (GAO), the investigative arm of Congress, to

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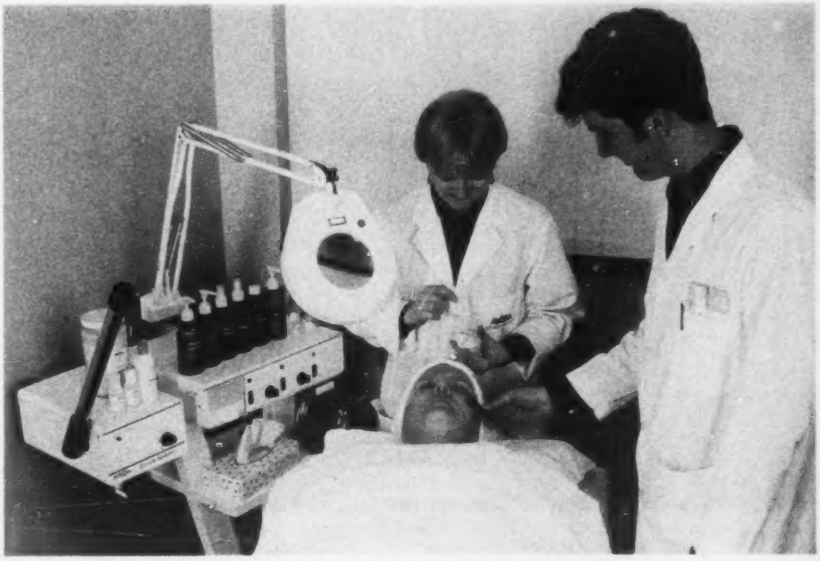
look at the issue, particularly FDA's regulatory authority over those products. GAO met with FDA and CTFA and decided to terminate the investigation in mid-1993. Following that, a study conducted by the American Cancer Society published in the Feb. 2 issue of the *Journal of the National Cancer Institute* showed that there are no credible links between hair dye use and cancer. FDA came to the same conclusion.

On another front, the industry continues to fight to keep up with a growing number of state air quality regulations. In steps implemented during the past five years, the California Air Resources Board has required the reformulation of several products including hair care products and antiperspirants and deodorants in an attempt to reduce their concentrations of volatile organic compounds (VOCs) that are said to contribute to smog.

Following California's lead, last year Arizona, Texas, and Rhode Island each moved toward wholesale adoption of the California regulations. As additional states join the fray, they likely will adopt regulations that vary from those in California, making it more difficult for producers to keep up with them, says CTFA's vice president and general counsel, Thomas J. Donegan. This issue "underscores the need for national uniformity of regulations."

To help cosmetics and toiletries companies proactively respond to the demands that these regulations might have on their businesses, National Starch, as a supplier of ingredients, is focusing much of its efforts in the development of new polymers and systems for low-VOC products, says Barry Lothian, the company's business manager for personal care polymers. For example, in late 1993 National Starch introduced Lovocryl 47, a polymer that helps overcome many of the problems of formulating with water in low-VOC hair sprays.

While the industry grapples with regulations relating to outdoor air quality, it is also monitoring growing concern about indoor air quality. Regulators are focusing on asbestos and secondhand smoke as well as the use of everyday products, like cosmetics and fragrances. "We're fighting this on a number of fronts," says Gerald N. McEwen, vice president of science at CTFA.



Aveda technicians test facial makeup formulations.

"As often happens, special interest groups in California already have taken this issue to extremes by trying to restrict the wearing of fragrances or scented products," which might affect people claiming to have multiple chemical sensitivity, says McEwen. For example, at one point San Francisco city policy requested people "to refrain from wearing perfumes or scented products" to public meetings. However, CTFA and the local retailing community worked together and were able to change the policy.

"There now is no mention of our products anywhere in the policy," says Irene L. Malbin, CTFA's vice president for public affairs. That won't be the end of this issue, however. The issue linking multiple chemical sensitivity with fragrances has attracted the attention of other cities and counties in California, and other states could potentially join in the debate.

The industry is also concerned about potential future legislation that would regulate personal care products, including baby shampoos, relative to their levels of potentially harmful by-products. Dioxanes and nitrosamines that are suspected carcinogens and trace by-products in certain surfactant production processes are already being scrutinized in European and Asia-Pacific markets, says Rhône-Poulenc's Manier. In anticipation of by-product regulation in the U.S., he says, Rhône-Poulenc is "working to reduce by-products production in every one of our processes."

Determining the impact of new raw materials and their by-products on consumers is becoming more difficult because of conflicting pressures within the animal testing debate. Cosmetics and toiletries companies, reacting to consumer demands, are asking for ingredients that have not been tested on animals, but at the same time, FDA has not yet approved the use of in-vitro tests as an alternative to animal tests. "The situation is perplexing. If a company has a new ingredient, it still needs to verify that it is safe. The question is how," says Lonza's Kosiek. "It would be a lot easier if there was one standard."

For now, CTFA continues to oppose bans on animal testing. To date, no state has enacted a bill banning animal testing. Over the past eight years, however, CTFA has defeated more than 50 such bills in 12 states. And so far this year, the association has been fighting bills in Vermont, Massachusetts, New York, and Illinois. "Our goal, of course, is to preserve the ability to conduct product safety testing in animals when necessary for new products and formulations," says Petrina.

CTFA has been successful in defeating animal testing legislation partly because it has been committed to developing alternatives to animal testing, putting a lot of technical resources into this effort over the past 15 years, says E. Edward Kavanaugh, CTFA president. The association is supporting research programs at Johns Hopkins University and Battelle Memorial Institute, and has also joined with the Japan Cosmetics Industry Association and with

European trade organizations in a global program.

Although FDA has not yet accepted any alternatives to tests on animals, many companies predict that the agency will have to change its stance sooner or later. Anticipating this, Rhône-Poulenc is doing no more animal tests on any of its surfactants or suggested formulations, says Manier. One problem with in-vitro tests has been the lack of correlation between irritation data obtained in animal tests and data collected in tests done in a synthetic media. However, Rhône-Poulenc says it has developed an in-vitro test with which it is now getting more than 80% concordance with numbers obtained in animal tests. "And we feel very comfortable with those results."

The avoidance of animal testing is just one of many claims that cosmetics and toiletries firms are including more often on label copy in an effort to attract the more environmentally sensitive consumer. These claims are creating much confusion in the industry because there are no national guidelines that define what these claims really mean. This issue gained more momentum last October when President Bill Clinton signed an executive order directing federal agencies to buy environmentally preferable products when possible. To carry out the executive order, EPA has drafted government purchasing guidelines to use in deciding whether a product is "environmentally preferable."

EPA's proposed "concept paper" on general environmental characteristics of products recommends the "absence of aesthetic additives (such as fragrance or dyes) that provide cosmetic advantages only." In opposition to the recommendation, in February CTFA testified at a public meeting that it "strongly believes that the presence of fragrances or dyes in products should not be a consideration in determining the environmental preferability of products." In response, the EPA panel has agreed to delete the recommendation from the second draft of the guidelines, which is due later this month.

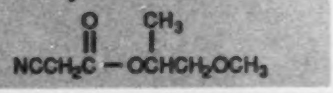
Although CTFA was successful in driving home this point, this issue is not completely behind the industry. The final guidelines "could literally change the future of the chemical industry" depending on what they propose, says Steve Ashkin, vice president of Rochester Midland, Rochester, N.Y.-based specialty chemicals producer that has developed an environmentally friendly product line of detergents and hand soaps.

CTFA realizes that it will be waging an uphill battle over the next few years as it carries out its mission to "provide its members with maximum flexibility in the marketplace without unreasonable government interference. [FDA Commissioner] Kessler is always searching for new crusades," says Hutt. "Our industry must be very careful not to give FDA an irresistible opportunity—an easy opening—to march in and make an example of one of our products or companies. Cosmetic companies must strengthen efforts to ensure proper labeling and manufacturing, so that cosmetics remain a low priority at FDA." ☐

PRODUCT PROSPECTUS

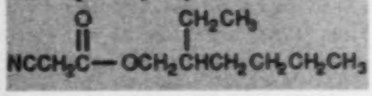
NEW Organic Intermediates

2-Methoxy isopropyl Cyanoacetate



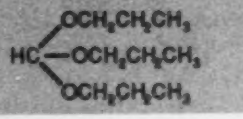
$NCCH_2\overset{\overset{O}{\|}}{C}-O\overset{\overset{CH_3}{|}}{C}HCH_2OCH_3$

2-Ethylhexyl Cyanoacetate



$NCCH_2\overset{\overset{O}{\|}}{C}-OCH_2\overset{\overset{CH_2CH_3}{|}}{C}HCH_2CH_2CH_2CH_3$

Tri-n-propylorthoformate



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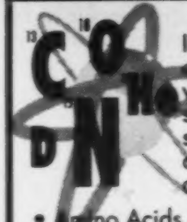

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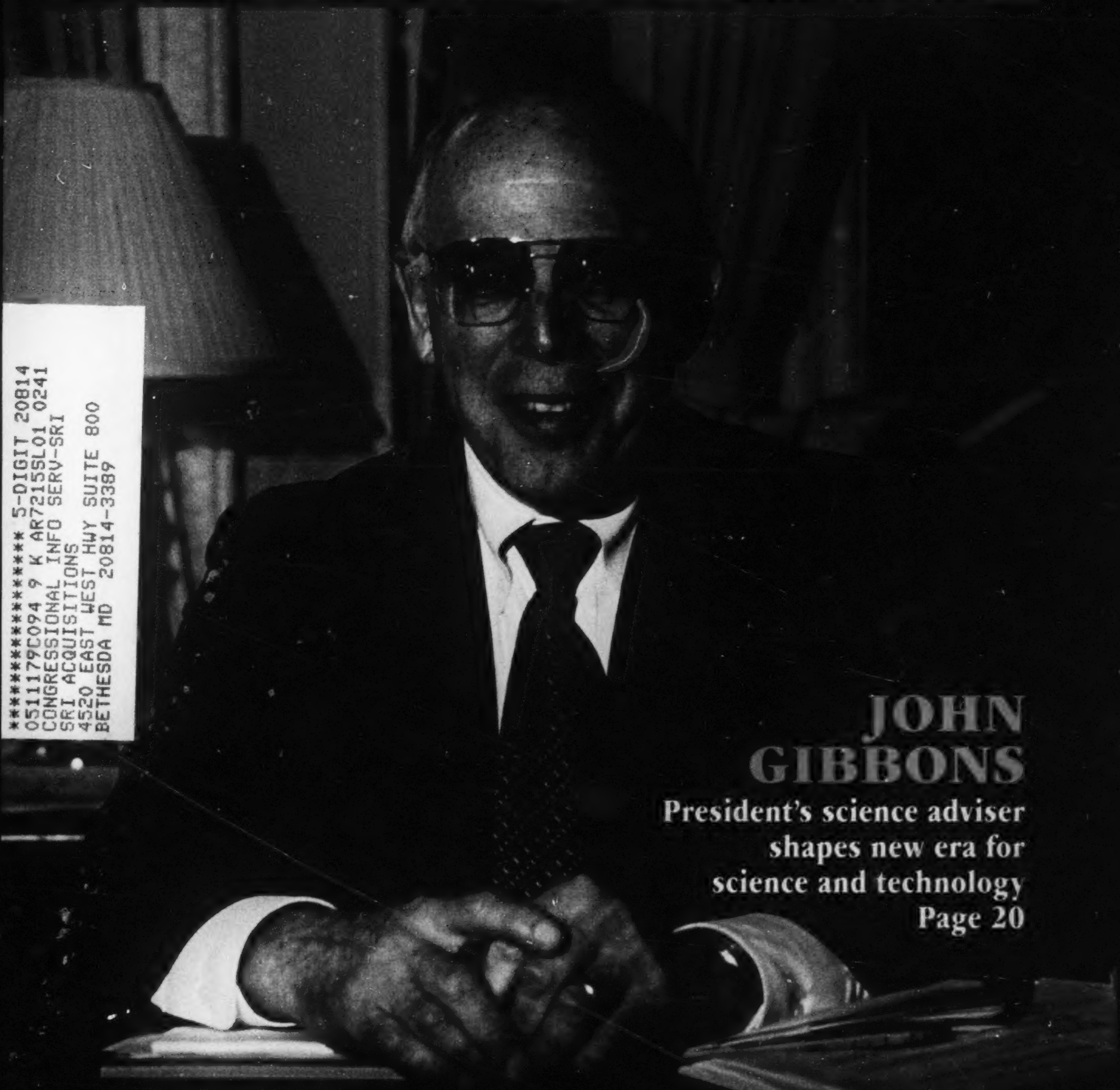
CHEMICAL & ENGINEERING NEWS

C&EN

APRIL 11, 1994

A1250-1

TOP 50 CHEMICAL PRODUCTS IN U.S. GROW MODESTLY IN 1993 PAGE 12



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JOHN GIBBONS

President's science adviser shapes new era for science and technology
Page 20

CHEMICAL & ENGINEERING NEWS

C&EN

APRIL 11, 1994

NEWS OF THE WEEK

- Natural gas in geologic deposits may have been produced by catalytic influences of sedimentary rock on kerogen rather than by thermal decomposition of organic matter. **Page 4**
- Isotopic tests indicate North Korea may have produced much more plutonium than it admits, says the International Atomic Energy Agency. **Page 5**
- Coverup by a tobacco company of a study that indicates nicotine is addictive—at least in rats—is charged by chairman of House panel examining possible regulation of cigarettes. **Page 6**
- Chemical stocks were affected by the stock market plunge of the past two weeks, and their prices fell significantly. **Page 6**
- U.K.'s Courtaulds and Germany's Hoechst have completed the merger of their viscose rayon and acrylic fibers operations in Europe, forming the second largest European producer of cellulosic fibers. **Page 7**
- Clearer rules, a two-stage review system, and public explanation of decision-making are some of the key recommendations of a study of NSF's major grant-awarding process. **Page 7**

COVER: Photo by C&EN's David J. Hanson

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CENEAR 72 (15) 1–72
ISSN 0009-2347

BUSINESS

Production of C&EN's Top 50 chemicals increased moderately in 1993, paced by organics, which were up nearly 10%; output of inorganics, however, slipped almost 1%. **Page 12**

Polymers production increased nearly 3% last year, reaching a new high of 67.4 billion lb. **Page 15**

European chemical industry had higher sales and earnings than expected last year, with the notable exception of petrochemicals; outlook for 1994 is brighter. **Page 17**

SCIENCE/TECHNOLOGY

Computer-aided molecular design is evolving to satisfy customer needs as molecular modeling and computational chemistry bid to become mainstream activities. **Page 31**

BOOKS

"Nobel Prize Women in Science: Their Lives, Struggles and Momentous Discoveries" provides an eye-opening look at 14 brilliant scientists and the barriers they faced. **Page 41**

ACS NEWS

Investigations of six mass firings of chemical professionals have been completed, indicate that employment picture is worse for older, experienced workers. **Page 45**

ACS Lehigh Valley Section celebrates its 100th anniversary with a full day of activities. **Page 47**

MEETINGS

Program of ACS Joint 26th Central & 27th Great Lakes Regional Meeting features nearly 600 papers and a special program for undergraduate students. **Page 51**

GOVERNMENT

After a little more than a year as the President's science adviser, John Gibbons talks about his work, changing national and international science policy, and what it's like to work in the Clinton White House. Page 20

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LETTERS

Bromine, biomass burning

In the report by S. Manö and M. O. Andreae [*Science,* **263,** 1255 (1994)] and the accompanying perspective by R. J. Cicerone [*Science,* **263,** 1243 (1994)] on the emission of methyl bromide from burning biomass, the role of the heat and smoke plume in getting this source of methyl bromide to the stratosphere is not mentioned. The rapidly rising plumes carrying it and other halogenated organics may well make such burnings the source of over 90% of the bromine in the stratosphere and of a much larger percentage of the chlorine than is currently accepted. In addition, the mass of materials in the smoke will greatly reduce photochemical reactions that destroy many halogenated compounds released by people or the oceans.

In the case of pesticide use, Cicerone indicates that the global release of methyl bromide is based on all of the used chemical escaping to the atmosphere. With grain fumigation, reactions altering essential biochemicals have been known for some years [*J. Sci. Food Agric.,* **6,** 269 (1955) and cited papers; *J. AOAC,* **72,** 815 (1989)]. Similar reactions probably occur to some extent in soils, so the initial contribution to the atmosphere from pesticide use may be quite a bit lower than the value cited by Cicerone.

Consequently, this newly discovered source of methyl bromide emission appears to be the one that needs much more control than the other emissions. And a major confirmation of the role of this emission has evolved these past few months as a result of the huge fires in Australia and Ethiopia. The upcoming ozone hole measurements ought to show some very significant shifts indicating that major programs to stop biomass burning are needed as the key step to stop ozone losses in the stratosphere.

James A. Singmaster III
Fremont, Calif.

More on Nobel Laureates

In his review of "Nobel Laureates in Chemistry 1901–1992" (C&EN, Feb. 14, page 32), George B. Kauffman ignores the fact that numerous chemists have been honored by the award of the Nobel Prize in Physiology or Medicine for studies in chemistry. His conclusions on such topics as the types of chemists who win the award during a given historical period, or when the last woman chemist won the prize, are not correct when considered in this context.

Work in medicinal chemistry and in the chemistry of natural products is as likely to be recognized for its importance to medicine or physiology as it is for its importance to chemistry. Examples include the medicine or physiology award to chemists like Paul Ehrlich, the father of medicinal chemistry (1908); Gerhard Domagk (sulfonamides, 1939); Edward A. Doisy (steroids, 1943); Edward C. Kendall and Tadeus Reichstein (corticoids, 1950); Daniel Bovet (antihistamines, 1957); Konrad Bloch and Feodor Lynen (steroid biosynthesis, 1964); and Roger Charles L. Guillemin and Andrew V. Schally (peptide hormones, 1977). Six years ago, Gertrude B. Elion and George H. Hitchings were awarded the prize (1988) for their design, synthesis, and studies of antineoplastic and antiviral drugs.

But Victor J. Linnenbom's letter (C&EN, March 28, page 3) commenting on Kauffman's review in which Linnenbom asserts that "merit [is] the sole criterion in selecting the laureates" must have been written in a parallel universe. One obvious additional criterion is that the recipient has to be alive. Given the fact that the prize is sometimes not awarded until decades after a discovery, it is possible for a deserving would-be laureate to die before he or she can be recognized. And like many human institutions, the Nobel Prize is subject to internal and external political pressures. Domagk was actually forced to decline the prize by the Nazis in 1939, but received a gold medal in lieu of the prize money in 1947. Robert B. Woodward did not receive the prize until 1965, following the death of another laureate who opposed the award to Woodward. And lastly, anyone who does not believe that women in science face greater obstacles to success than men should read Gertrude Elion's autobiographical essay in *Annual Reviews of Pharmacology* (1993).

Manfred E. Wolff
Senior Vice President, R&D
ImmunoPharmaceutics Inc.
San Diego

Correction

• March 28, page 37: Howard E. Simmons III should have been identified as a research associate at DuPont not as emeritus vice president for research, his recently retired father.

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Top 50 Chemicals Production Rose Modestly Last Year

■ ***Output rose nearly 3% in 1993; organics set the pace, up nearly 10%, while inorganics declined almost 1%***

Marc S. Reisch,
C&EN Northeast News Bureau

Production of the 50 largest volume chemicals rose modestly in 1993 following a fairly substantial increase in output in 1992. Chemical industry economists and observers attribute the increase to fairly strong U.S. markets, as the pace of U.S. economic expansion continued to quicken.

According to C&EN's annual ranking of the Top 50 chemical products, total production of the group rose to nearly 685 billion lb last year, up almost 3% from 1992. That increase followed a 5% gain in production of the Top 50 chemicals in 1992.

In 1992, the U.S. economy—and Top 50 chemical production—got stronger as both shrugged off the effects of the 1991 recession. The reawakening economy, combined with continued strong exports, helped considerably to boost chemical output in 1992. But in 1993, points out DuPont chief economist Richard A. Stuckey, chemical exports were fairly flat. Western Europe, a large customer of U.S. chemicals, was mired in a recession, thus cutting demand for all types of U.S. products.

Stuckey says U.S. chemical production benefited in 1993 particularly because of increased demand from motor vehicle, housing, and home furnishings customers. As consumer interest rates reached their lowest point in years, buyers, who earlier could not afford new cars or homes because of high interest rates, were back in the market, he explains. Motor vehicle production climbed and with it rose demand for the plastics and rubber components fashioned from chemical intermediates. Housing starts also increased, and along with them came an increase in demand for adhesives and plastics produced with materials the U.S. chemical industry supplies. To furnish those new homes, consumer demand rose for such items as nylon carpet and olefin upholstery—all produced from U.S. chemical products.

"Clearly, strong housing and automotive industries were important to the growth of industrial shipments in 1993," concurs Allen J. Lenz, the Chemical Manufacturers Association (CMA) director of trade and economics. Export markets were weak, he also says. Had those markets been stronger in 1993, they would

About the Top 50 list of chemical products

Government data, trade association figures, and industry estimates all go into preparing C&EN's annual list of the Top 50 chemical products in the U.S., ranked by production volume. The federal government is relied upon most heavily, but when government figures are not available, other sources, primarily trade associations, are used. Industry sources and C&EN estimates are used only when other data are lacking.

Government data are not always accurate—they are only as good as the information that individual companies report. But they are an objective measure of production extending back many years. Therefore, relatively accurate indications of growth can be made on a consistent basis.

At this time of year, C&EN has access only to preliminary reports of production for 1993. When the government and trade associations issue their final reports, the outcome can change, sometimes dramatically. As a result, the production figures, as well as rankings, for earlier years that appear in the table on page 13 are different in some cases from those published in last year's Top 50 article (C&EN, April 12, 1993, page 11). In this year's compilation, the 1992 ranking of 17 chemicals is different from the 1992 ranking published last year.

The list itself covers production figures for the U.S. and includes chemicals produced for export. Candidates for the list include all basic, intermediate, and chemically homogeneous finished products. These range from chemical building blocks like ethylene and propylene to downstream products like vinyl acetate and ethylene glycol.

The roster includes basic inorganic chemicals, but does not include what C&EN considers to be minerals, such as salt, gypsum, and sulfur. Lime is included because it is processed and has many chemical and industrial applications. Refractory (dead burned) dolomite is excluded in lime production.

In the organics list, petrochemical feedstocks such as ethane, butane, and propane are excluded arbitrarily because they are considered to be products of oil companies and because they have many nonchemical uses.

There are other gray areas besides lime and petrochemical feedstocks. For example, the basic aromatics—benzene, toluene, and xylene—are included.

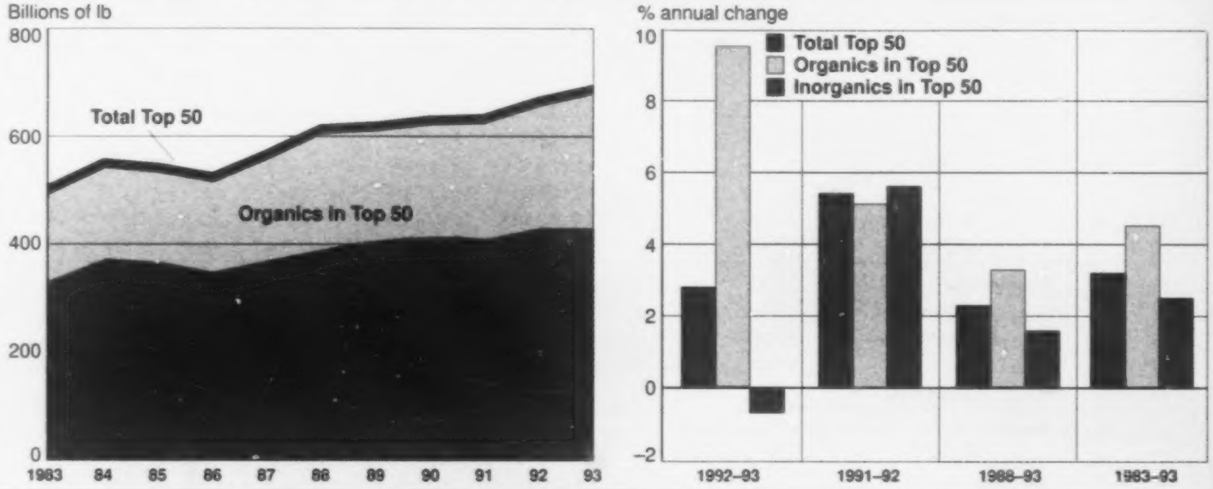
Production figures are published by the government in a variety of units—pounds, tons, cubic feet, gallons, metric tons, and, most recently, kilograms and liters. Where the latter two units are used, they have been converted, where appropriate, into the common units historically used as points of reference. To provide an accurate ranking and to make comparison of production volumes easier, C&EN lists production not only in common units, but also converted to pounds.

Organics led last year's Top 50 chemicals production increase

Rank			Billions of lb		Common units[b]		Average annual change			
1993	1992[a]		1993	1992	1993	1992	1992–93	1991–92	1988–93	1983–93
1	1	Sulfuric acid	80.31	89.72	40,153 tt	44,860 tt	−10.5%	3.5%	−1.2%	0.7%
2	2	Nitrogen	65.29	60.51	901 bcf	835 bcf	7.9	10.0	4.5	4.9
3	3	Oxygen	46.52	43.46	562 bcf	525 bcf	7.0	11.2	4.5	5.0
4	4	Ethylene	41.25	40.93	41,251 mp	40,931 mp	0.8	2.4	2.1	3.7
5	6	Lime[c]	36.80	35.71	18,400 tt	17,857 tt	3.0	3.4	2.1	2.2
6	5	Ammonia	34.50	36.59	17,252 tt	18,295 tt	−5.7	6.6	0.5	2.1
7	8	Sodium hydroxide	25.71	24.50	12,854 tt	12,249 tt	4.9	4.6	4.1	2.3
8	9	Chlorine	24.06	23.51	12,028 tt	11,757 tt	2.3	2.9	1.3	1.9
9	19	Methyl *tert*-butyl ether	24.05	10.88	24,053 mp	10,877 mp	121.1	13.7	33.5	39.9
10	7	Phosphoric acid	23.04	25.58	11,521 tt	12,792 tt	−9.9	6.1	−0.2	1.7
11	10	Propylene	22.40	23.43	22,403 mp	23,426 mp	−4.4	8.7	1.1	4.8
12	11	Sodium carbonate[d]	19.80	20.84	9,899 tt	10,419 tt	−5.0	4.9	0.5	1.6
13	15	Ethylene dichloride	17.95	15.15	17,949 mp	15,153 mp	18.5	10.5	6.6	4.5
14	13	Nitric acid	17.07	16.09	8,537 tt	8,043 tt	6.1	1.5	1.3	2.1
15	14	Ammonium nitrate[e]	16.79	15.66	8,394 tt	7,832 tt	7.2	0.7	2.3	3.0
16	12	Urea[f]	15.66	17.96	7,832 tt	8,981 tt	−12.8	10.4	−0.2	2.7
17	16	Vinyl chloride	13.75	11.31	13,748 mp	11,309 mp	21.6	−3.3	8.7	7.2
18	17	Benzene	12.32	11.27	1,672 mg	1,530 mg	9.3	−1.9	1.0	3.1
19	18	Ethylbenzene	11.76	11.11	11,759 mp	11,111 mp	5.8	25.2	3.4	4.1
20	19	Carbon dioxide[g]	10.69	10.88	5,347 tt	5,439 tt	−1.7	5.2	1.1	3.2
21	23	Methanol	10.54	8.08	10,544 mp	8,084 mp	30.4	-7.1	5.3	2.8
22	21	Styrene	10.07	9.00	10,066 mp	9,001 mp	11.8	10.9	2.3	4.0
23	29	Terephthalic acid[h]	7.84	5.64	7,839 mp	5,638 mp	39.0	−26.2	−5.2	3.4
24	22	Formaldehyde[i]	7.61	8.28	7,605 mp	8,280 mp	−8.1	25.2	3.9	3.4
25	25	Xylene	6.84	6.39	949 mg	888 mg	6.9	1.2	4.5	2.7
26	24	Hydrochloric acid	6.45	7.13	3,224 tt	3,566 tt	−9.6	8.0	4.1	2.9
27	27	Toluene[j]	6.38	5.81	880 mg	801 mg	9.8	−7.7	0.1	1.2
28	28	*p*-Xylene	5.76	5.66	5,757 mp	5,656 mp	1.8	5.7	0.6	3.4
29	26	Ethylene oxide	5.68	5.83	5,684 mp	5,830 mp	−2.5	11.1	−0.9	0.3
30	30	Ethylene glycol	5.23	5.13	5,230 mp	5,129 mp	2.0	6.6	−1.1	1.7
31	31	Ammonium sulfate	4.80	4.78	2,398 tt	2,391 tt	0.3	6.6	0.6	2.1
32	32	Cumene	4.49	4.67	4,489 mp	4,666 mp	−3.8	12.0	0.2	3.0
33	34	Phenol[k]	3.72	3.61	3,718 mp	3,607 mp	3.1	0.2	0.9	3.5
34	35	Acetic acid	3.66	3.59	3,656 mp	3,594 mp	1.7	−0.6	3.0	2.7
35	33	Potash[l]	3.31	3.86	1,500 tmt	1,750 tmt	−14.3	0.1	−0.3	0.5
36	37	Carbon black	3.22	3.02	3,224 mp	3,016 mp	6.9	10.8	2.0	2.6
37	36	Butadiene[m]	3.09	3.23	3,094 mp	3,233 mp	−4.3	5.8	−0.5	2.8
38	40	Vinyl acetate	2.83	2.66	2,827 mp	2,657 mp	6.4	−2.7	2.0	3.7
39	39	Propylene oxide	2.73	2.70	2,727 mp	2,700 mp	1.0	8.0	−2.6	3.9
40	41	Titanium dioxide	2.56	2.51	1,280 tt	1,253 tt	2.2	14.4	4.6	5.4
41	38	Acrylonitrile	2.51	2.83	2,509 mp	2,829 mp	−11.3	6.8	−0.8	1.6
42	42	Acetone	2.46	2.43	2,463 mp	2,434 mp	1.2	3.7	1.4	2.9
43	44	Aluminum sulfate	2.23	2.09	1,113 tt	1,047 tt	6.3	−11.6	−2.0	0.1
44	43	Cyclohexane	2.00	2.24	2,000 mp	2,242 mp	−10.8	−2.9	−2.7	1.9
45	45	Sodium silicate	1.97	1.82	983 tt	912 tt	7.8	4.8	3.9	3.0
46	46	Adipic acid	1.56	1.56	1,560 mp	1,560 mp	0	1.0	−0.5	2.0
47	47	Sodium sulfate[n]	1.44	1.52	718 tt	761 tt	−5.7	−4.2	−2.6	−1.7
48	48	Calcium chloride[o]	1.40	1.39	700 tt	694 tt	0.8	7.9	−0.9	−2.0
49	49	Caprolactam	1.36	1.38	1,358 mp	1,378 mp	−1.4	7.4	1.5	3.3
50	—	*n*-Butyl alcohol	1.33	1.26	1,327 mp	1,263 mp	5.1	−3.9	−6.5	4.8
TOTAL ORGANICS			**256.81**	**234.03**			**9.7%**	**4.8%**	**3.3%**	**4.5%**
TOTAL INORGANICS			**427.95**	**431.18**			**−0.7%**	**5.6%**	**1.6%**	**2.5%**
GRAND TOTAL			**684.76**	**665.21**			**2.9%**	**5.3%**	**2.3%**	**3.2%**

a Revised. **b** **tt** = thousands of tons, **bcf** = billions of cubic feet, **mp** = millions of pounds, **mg** = millions of gallons, **tmt** = thousands of metric tons. **c** Except refractory dolomite. **d** Natural and synthetic. **e** Original solution. **f** 100% basis. **g** Liquid and solid only. **h** Includes both acid and ester without double counting. **i** 37% by weight. **j** All grades. **k** Synthetic only. **l** K_2O basis. **m** Rubber grade. **n** High and low purity. **o** 75% basis, solid and liquid.

Top 50 chemicals production grew to 685 billion lb in 1993



have boosted the industry's output even further.

Bruce Pickover, vice president of industry consultant Chem Systems, Tarrytown, N.Y., notes that weak crude oil and petrochemical prices put constraints on production in 1993. Producers drew down inventories instead of increasing production to meet demand, he says, "further affecting production." But while he agrees that chemical exports were not strong in 1993, he believes that in the long term U.S. chemical exports will recover. Not much new capacity for bulk chemical production is being built worldwide, says Pickover, and he expects to see increases in overseas demand for U.S. chemical products.

Looking to 1994, Pickover says that a continuing increase in domestic demand for chemicals on the Top 50 list will help improve the industry's use of its operating capacity. While he estimates the average operating rate for the Top 50 chemicals in 1993 was 84% of capacity, he says he would estimate that rate currently at 86%. Operating rates for bulk chemicals are up now for the first time in several years, he says.

CMA's Lenz points out that in 1994 consumer confidence is continuing to grow, vehicle sales are continuing to rise, and construction spending is still increasing, as are sales of new homes. But he is wary of recent consumer interest rate increases and their potential to put a damper on automotive and construction markets. He nevertheless predicts that U.S. gross domestic product will grow 3% in 1994 above 1993, and along with it, he expects U.S. chemical production to increase 3 to 4% in 1994.

DuPont's Stuckey thinks that recent declines in the U.S. bond and equity markets will "make households feel poorer." Where people may have planned to cash in on gains of the past year and redeem securities to purchase furniture or appliances, they may be reluctant now to do so, he says. Rising interest rates, too, will hurt consumer markets in 1994, though industrial markets may not experience the same effect and could continue to expand. Overall, says Stuckey, 1994 will see chemical output increase faster than last year's 3% pace. Help from exports, though, will depend on "the timing and pace of a European [economic] recovery," he says.

In C&EN's compilation of the Top 50 chemicals, sulfuric acid remained the largest volume chemical produced in the U.S., as it has been for many years, far outpacing any other chemical product. Output in 1993 was 80 billion lb, down 11% from the year before. In 1992, sulfuric acid production rose nearly 4% from 1991 to 90 billion lb.

Nitrogen remained a distant second, both in 1993 and 1992. Production of nitrogen rose nearly 8% in 1993 over the previous year to 65 billion lb. In 1992, nitrogen production was up 10% from a year earlier to nearly 61 billion lb.

Of the Top 50 chemicals, 29 were organic chemicals, accounting for some 38% of total production, compared with 35% in 1992. Combined organics production increased nearly 10% in 1993 from the previous year, after a more modest increase of about 5% in 1992. Over the five-year period from 1988 to 1993, combined production of organic chemicals among the Top 50 increased an average of 3% per year. Over the decade from 1983 to 1993, however, their output grew at a faster pace, close to 5% per year.

Much of the growth in the organics group came from a more than twofold production increase of methyl *tert*-butyl ether (MTBE) to 24 billion lb in 1993, as increasing amounts of the fuel oxygenate were used to meet Clean Air Act requirements. The growing use of the compound boosted it from 19th in the 1992 listing to ninth last year.

Indeed, 19 of the 29 organics posted production increases in 1993. Besides MTBE's big increase, production of terephthalic acid grew at a double-digit pace—up 39% to nearly 8 billion lb—as demand for polyester film and resins grew. Its strong growth moved it to 23rd place among the Top 50 from 29th place in 1992. Terephthalic acid production had declined 26% in 1992 to about 6 billion lb.

Methanol production also grew rapidly, up 30% in 1993 to about 11 billion lb, placing it 21st on the list. In 1992, methanol production dropped 7% from 1991 to 8 billion lb, ranking it 23rd among the Top 50. Vinyl chloride production rose 22% in 1993 to nearly 14 billion lb, placing it 17th on the list, down from 16th place in 1992, when output was closer to 11 billion lb, a 3% decline from 1991.

Also showing double-digit increases in 1993 production were ethylene dichloride and styrene. Ethylene dichloride production rose about 19% in 1993 to 18 billion lb, placing it 13th on the list. In 1992, it ranked 15th, with output at 15 billion lb, up 11% from the previous year. Styrene production rose 12% in 1993 to 10 billion lb, placing it 22nd on the list. In 1992, styrene output increased 11% to 9 billion lb, and it was ranked 21st in the Top 50.

Whereas overall organic production grew in 1993, overall production of inorganic chemicals among the Top 50 did not. Combined output of the 21 inorganic chemicals decreased almost 1% from the previous year, following a nearly 6% increase in 1992. Over the five-year period from 1988 to 1993, combined output of inorganic chemicals grew at an average annual rate of about 2% per year. Over the most recent decade, production of inorganics grew at a little closer to 3% per year.

Of the inorganics, 13 of the 21 posted production increases, led by second-place nitrogen, with its 8% increase to 65 billion lb. Sodium silicate also had a good year, with output also up 8% to nearly 2 billion lb. However, it continues to occupy the same 45th ranking it held in the 1992 Top 50.

The 1993 Top 50 listing contains one new addition: *n*-butyl alcohol. It displaces isobutylene on the 1992 list.

Output of polymers increased almost 3%

Overall U.S. production of commercial polymers, including plastics, synthetic fibers, and synthetic rubber, edged up nearly 3% in 1993 from 1992. As a result, production reached a new high last year: 67.4 billion lb. However, output growth was stronger in 1992, when polymer production rose 5% over the previous year and totaled nearly 66 billion lb.

Of the three groups of polymers surveyed, plastics production accounts for more than three quarters of total polymer production. Plastics also led overall polymer growth in 1993, with a nearly 3% production rise to 53 billion lb. Synthetic fibers production increased close to 3% to just over 9 billion lb, but synthetic rubber output declined nearly 2% to about 5 billion lb.

Production of thermosetting resins grew at a fairly impressive rate of more than 8% to 6.9 billion lb, following more than 7% growth in 1992. Thermoplastic resins production, however, rose only 2% in 1993 to slightly more than 46 billion lb. This came after a nearly 5% increase in 1992.

Among thermosetting plastics, output of melamine resins grew at an annual rate of more than 16% in 1993, following an 18% increase in 1992. Urea resins turned in the next best performance, up nearly 13% in 1993, compared with a much slower 4% increase in 1992. Production of unmodified epoxy resins also showed double-digit growth in 1993, up nearly 12%, compared with an 8% decline a year earlier. Unsaturated polyester resins registered a nearly 8% increase in 1993, after a more than 9% increase in 1992. Phenol and other tar acid resins showed a modest but still respectable 5% production increase in 1993, following a 10% increase in 1992.

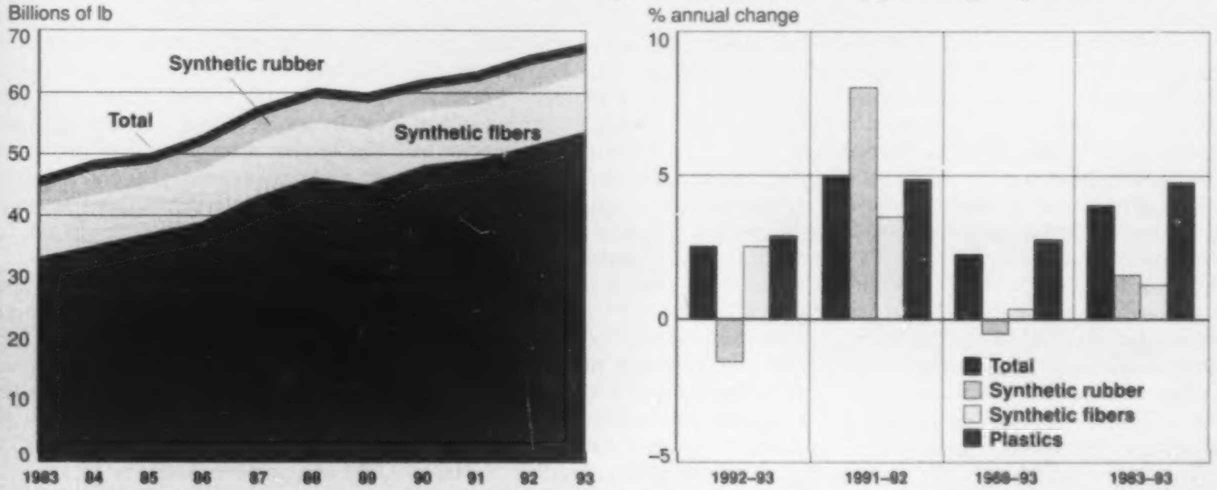
In the thermoplastic resins category, polystyrene registered the best production increase in 1993, up 5%, following an almost 3% increase in 1992. The next best performer was the polyvinyl chloride and copolymers category, up almost 3% in 1993, after a nearly 9% production increase in 1992. Polypropylene production rose only 2% in 1993, after it edged up 1% in 1992. Both low-density and high-density polyethylene production increased a modest 1% in 1993. Production of the low-density resin grew nearly 3% in 1992, and that of the high-density resin grew more than 6% in 1992.

Synthetic fiber output continued its slow but steady rise. Total output reached 9.3 billion lb in 1993, up nearly 3%, a little slower than the 4% rate in 1992.

Cellulosic fiber production continued to rise about 2% in 1993 as well as 1992. Manufacture of both rayon and acetate fiber produce much waste. Over the past 10 years, heavy environmental pressure has forced cellulosic fiber production down an average 2% per year. However, the production rise in 1992 and 1993 reflects continued demand for the fibers in fashion apparel.

Although the production of noncellulosic fibers has its own environmental pitfalls, these are not so great as they are with cellulosic fibers. Noncellulosic fibers are also more widely used because they are easier to produce and process in knitting and weaving machines.

Plastics and synthetic fiber output rose, but synthetic rubber slipped slightly in 1993



Total polymer production exceeded 67 billion lb in 1993

	Billions of lb		Common units				Average annual growth			
	1993	1992	1993	1992	1988	1983	1992–93	1991–92	1988–93	1983–93
PLASTICS (common units = millions of lb)										
Thermosetting resins[a]	**6.87**	**6.34**	**6,866**	**6,335**	**6,588**	**5,254**	**8.4%**	**7.2%**	**0.8%**	**2.7%**
Phenol and other tar acid resins	3.08	2.92	3,078	2,923	3,066	2,484	5.3	10.0	0.1	2.2
Urea resins	1.74	1.55	1,744	1,548	1,425	1,172	12.7	4.4	4.1	4.1
Polyesters (unsaturated)	1.26	1.18	1,264	1,175	1,404	1,084	7.6	9.3	−2.1	1.5
Epoxies (unmodified)	0.51	0.46	510	457	486	334	11.6	−8.0	1.0	4.3
Melamine resins	0.27	0.23	270	232	207	180	16.4	18.4	5.5	4.1
Thermoplastic resins[a]	**46.19**	**45.23**	**46,194**	**45,231**	**39,608**	**27,799**	**2.1%**	**4.6%**	**3.1%**	**5.2%**
Low-density polyethylene	12.04	11.92	12,044	11,917	10,397	8,041	1.1	2.9	3.0	4.1
PVC and copolymers	10.26	9.99	10,257	9,989	8,350	6,066	2.7	9.0	4.2	5.4
High-density polyethylene	9.91	9.81	9,912	9,808	8,400	5,691	1.1	6.4	3.4	5.7
Polystyrene[b]	5.37	5.10	5,367	5,096	5,187	3,567	5.3	2.9	0.7	4.2
Polypropylene	8.61	8.42	8,614	8,421	7,274	4,434	2.3	1.1	3.4	6.9
TOTAL[a]	**53.06**	**51.57**	**53,060**	**51,566**	**46,196**	**33,053**	**2.9%**	**4.9%**	**2.8%**	**4.8%**
SYNTHETIC FIBERS (common units = millions of lb)										
Cellulosics[a]	**0.51**	**0.50**	**505**	**495**	**614**	**640**	**2.0%**	**1.9%**	**−3.8%**	**−2.3%**
Rayon[c]	0.28	0.28	278	275	400	411	1.1	0.7	−7.0	−3.8
Acetate[d]	0.23	0.22	227	220	214	229	3.2	3.3	1.2	−0.1
Noncellulosics[a]	**8.79**	**8.57**	**8,792**	**8,573**	**8,526**	**7,534**	**2.6%**	**3.7%**	**0.6%**	**1.6%**
Polyester	3.56	3.58	3,557	3,576	3,680	3,543	−0.5	4.8	−0.7	0
Nylon	2.66	2.56	2,664	2,556	2,670	2,418	4.2	0.8	0	1.0
Olefin[e]	2.14	2.00	2,138	2,002	1,588	902	6.8	7.3	6.1	9.0
Acrylic[f]	0.43	0.44	433	439	588	671	−1.4	−3.3	−5.9	−4.3
TOTAL[a]	**9.30**	**9.07**	**9,297**	**9,068**	**9,140**	**8,174**	**2.5%**	**3.6%**	**0.3%**	**1.3%**
SYNTHETIC RUBBER (common units = thousands of metric tons)										
Styrene-butadiene[g]	1.89	1.92	855	871	909	904	−1.8	3.3	−1.2	−0.6
Polybutadiene	1.03	1.02	465	461	407	333	0.9	11.1	2.7	3.4
Ethylene-propylene	0.58	0.58	261	265	263	175	−1.5	14.2	−0.2	4.1
Nitrile	0.14	0.13	64	59	76	55	8.5	3.5	−3.4	1.5
Other[h]	1.37	1.42	621	644	679	468	−3.6	10.8	−1.8	2.9
TOTAL[a]	**5.00**	**5.07**	**2,266**	**2,300**	**2,334**	**1,935**	**−1.5%**	**8.1%**	**−0.6%**	**1.8%**
GRAND TOTAL ALL POLYMERS	67.35	65.71					2.5%	5.0%	2.2%	4.0%

a Totals are for those products listed and may not add because of rounding. **b** No longer includes acrylonitrile-butadiene-styrene or styrene acrylonitrile resins; historical data are restated. **c** Includes acetate tow beginning with 1985. **d** Includes diacetate and triacetate yarn but does not include cigarette tow. Beginning with 1985, includes rayon yarn. **e** Includes olefin film, olefin fiber, spun-bonded polypropylene and vinyon. **f** Includes modacrylic. **g** Includes high-styrene latex. **h** Beginning with 1985, includes neoprene; historical data are restated. Also includes butyl, polyisoprene, chlorosulfonated polyethylene, polyisobutylene, and acrylic, fluoro, and silicone elastomers. **Sources:** Society of the Plastics Industry, Fiber Economics Bureau, Rubber Manufacturers Association, International Institute of Synthetic Rubber Producers

Noncellulosic fiber output increased nearly 3% in 1993, after a nearly 4% rise in 1992. Olefin and nylon fibers both benefitted as the housing market continued to expand in 1993 and carpeting demand rose. Olefin grew fastest, up nearly 7% in 1993, following a more than 7% rise in 1992. Olefin is seeing increasing use in area rugs and other floor coverings. Nylon production rose 4% in 1993, following an almost 1% increase in 1992. Polyester fiber output declined about 1%, after a nearly 5% rise in 1992. Acrylic fiber output continued its 10-year downward spiral, with production off more than 1% in 1993, following a 3% decline in 1992.

This year's polymers data include synthetic rubber production, which was not available for last year's compilation of production figures (C&EN, April 12, 1993, page 16). Synthetic rubber production slipped about 2% in 1993 to 5 billion lb, following a more than 8% increase in 1992. Nitrile rubber recorded the headiest growth of the group, with output up nearly 9% in 1993, following an almost 4% rise in 1992. Polybutadiene grew about 1% in 1993, after a much higher 11% growth rate in 1992.

Production of the three remaining categories of synthetic rubber declined in 1993. Both styrene-butadiene and ethylene-propylene elastomer production fell almost 2% in 1993. And production of a miscellaneous group, including neoprene, butyl, and polyisoprene, fell nearly 4%.

Last year, the International Institute of Synthetic Rubber Producers (IISRP) was unable to provide the breakout of U.S. production data that it had in the past. The government had halted its rubber production survey in 1990, and the Rubber Manufacturers Association discontinued the publication of its U.S. data at the same time.

An IISRP spokesman says that this year the group's internal reporting regulations allow it to again break out U.S. synthetic rubber production data for 1993 and previous years. Once again, the table and graphs accompanying this article include rubber production data for 1993 and previous years.

Marc Reisch

European chemical sales, earnings better than expected in 1993

Patricia L. Layman, C&EN London

Most sectors of the European chemical industry—petrochemicals being the notable exception—performed better last year than had been widely forecast at the beginning of the year, according to 1993 financial results just posted by chemical producers there.

What's more, the outlook for 1994 is even better. Progress may be slow, producers agree, and some trouble spots remain. However, producers are feeling less depressed as they see European economies beginning to stir from their doldrums, with demand picking up and overcapacity declining. That's especially encouraging because the European share of these companies' sales have declined more steeply than those overall.

Moreover, the recent price decrease for oil and its derivatives is helping chemical producers boost woefully low operating margins.

The rapid drop in oil prices is complicating chemical executives' plans and models for running their businesses. For example, as recently as early February, Brian K. Sanderson, chief executive of BP Chemicals, a subsidiary of British Petroleum, noted that the company is well on its way to meeting targets that were set expecting $18-per-barrel oil prices. "Now we are figuring at $16, with alternative plans for what to do at $14 per barrel."

In addition, as demand begins picking up, price increases are starting to hold, boosting profit margins as well. "One can't make too much of this," says Tony Cox, chemicals analyst with Kleinwort Benson, securities brokers in London, "but there may be some change of psychology in purchasing agents" that is allowing prices to firm. Customers will expect some pass-along of declining raw materials prices, he says, but "it will be possible for producers to widen their margins by not giving away all the benefits" of the oil price drop. He points to similarities with the oil price collapse in 1986, which coincided with the beginning of an earlier recovery of the chemical industry.

Such improvements can't come too soon for the European chemical industry. For example, at Dutch producer DSM, which posted a net loss in 1993—a result chairman Simon De Bree characterized as "downright poor"—average selling prices were almost 7% lower last year. The company's operating results for 1993 fell dramatically, mainly because of lower profit margins for virtually all products.

Indeed, for 1993, operating and profit margins remained troublesome throughout Europe. In their efforts to cope, many chemical companies have intensified restructuring efforts over the past year, shedding employees, closing plants, and selling operations, among other actions.

As Sir Denys Henderson, chairman of British producer ICI, puts it, "The results for 1993 are relatively encouraging in the context of a difficult global marketplace. With overall sales volumes virtually flat and prices under pressure, the improvement in profits [for ICI] from continuing operations essentially came from cost reductions and currency."

Restructuring costs hit commodity chemical companies especially hard. For example, France's Elf Aquitaine took a special provision of $68 million in the second half of 1993 for reorganizing its chemicals sector.

Similarly, at Total, also of France, where operating earnings from chemicals declined 14% from 1992, the company could find solace only in that the earnings performance could have been worse. "This result shows the segment's resistance to the recession, which hurt the main European specialty chemicals markets," says a Total executive. Resistance was helped in part, the company adds, by the sustained implementation of rationalization programs.

The chemical arm of Royal Dutch/Shell posted operating losses for the year of $604 million, compared with losses of $329 million in 1992. However, the company says, the 1993 loss included $496 million for restructuring—compared with only $95 million total for restructuring in 1991–92. Excluding special items, results for the year improved, benefiting from lower feedstock prices and cost reductions, the company says. And by the fourth quarter, the improvement was clear: a loss of $100 million, compared with a loss of $269 million in fourth-quarter 1992.

However, stringent cost-cutting programs have begun to pay off. In the Nordic countries, where economies have been particularly hard hit, Finland's Kemira points to the initial benefits in its operating performance from the major rationalization program it has undergone. The company pulled a pretax loss of nearly $60 million in 1992 into the black, with pretax profits of $5 million last year.

Similarly, at Norsk Hydro, of Norway, extensive restructuring steps taken in the agriculture division—essentially fertilizers—meant that the division showed a small operating profit for the year, following serious losses in both 1991 and 1992. Cuts in costs in agri-

European companies reported mixed financial results in 1993

	Sales	Net earnings	% change from 1992	
	($ Millions)		Sales	Net earnings
CHEMICAL COMPANIES				
Hoechst (Germany)	$26,560	$ 436	0.3%	−36%
BASF (Germany)	24,873	495	−3	88
Bayer (Germany)	23,653	765	−0.4	−13
Rhône-Poulenc (France)	13,680	313	−1	−16
ICI (U.K.)	12,449	204	12	def
Akzo (Netherlands)	8,322	277	−1	−15
Solvay (Belgium)	6,683	−194	−5	def
DSM (Netherlands)	4,054	−59	−10	def
Kemira (Finland)	2,046	5[a]	6	na
Laporte (U.K.)	1,319	56	47	30
Dyno (Norway)	1,096	41[a]	10	92
Lonza (Switzerland)	575	26	4	5
PHARMACEUTICAL COMPANIES				
Ciba (Switzerland)	15,307	1,202	2	17
Sandoz (Switzerland)	10,206	1,153	5	14
Zeneca (U.K.)	6,557	650	12	na
Schering (Germany)	3,093	147	2	−3

a Pretax. **def** = deficit. **na** = not available.

Oil and diversified firms awash in red ink last year

($ Millions)	Total sales	CHEMICAL OPERATIONS			
				% change from 1992	
		Sales	Operating earnings	Sales	Operating earnings
OIL & DIVERSIFIED COMPANIES					
Royal Dutch/Shell (U.K., Netherlands)	$93,555	$9,304	$ −604	12%	def
Elf Aquitaine (France)	35,605	8,490	−31	0	def
Veba (Germany)	39,242	5,826	−199	−1	def
Henkel (Germany)	7,999	4,599	na	1	—
British Petroleum (U.K.)	51,614	4,333	−102	−1	def
Norsk Hydro (Norway)	8,309	4,217	115	7	1,019%
Unilever (U.K., Netherlands)	41,148	3,456	409	19	15
Total (France)	23,005	3,124	244	−2	−14

def = deficit. **na** = not available.

culture, coupled with improved performance in the company's petrochemicals division—which just dipped into the red in 1992—gave the company its dramatic increase in operating profits for 1993.

But restructuring had negative effects on at least one specialties company—Henkel, the German chemicals and detergents producer. It directly attributes its 1993 profits decline to restructuring, as the company trimmed its work force by 2,000 through the year. It says the benefits of the cost-cutting will be reflected in this year's results.

However, although the economy is improving, the benefits will not be experienced this year throughout the European industry. At German oil company Veba, for example, officials say the chemicals division—essentially Hüls—will continue to shed jobs over the year; no profit for the division is expected until next year.

Sales poor in Europe for chemical companies

	% change from 1992	
	Total sales	European sales
CHEMICAL COMPANIES		
Hoechst (Germany)	0.3%	−9%
BASF (Germany)	−3	−8
Bayer (Germany)	−0.4	−10
Rhône-Poulenc (France)	−1	−9
ICI (U.K.)	12	−6
Akzo (Netherlands)	−1	−7
DSM (Netherlands)	−10	−11
Laporte (U.K.)	47	72
PHARMACEUTICAL COMPANIES		
Ciba (Switzerland)	2	−4
Zeneca (U.K.)	12	−1
DIVERSIFIED & OIL COMPANIES		
Shell (U.K., Netherlands)	12[a]	−2[a]
Henkel (Germany)	1[a]	−7[a]

[a] Chemical sales.

Still unquestionably troubling the industry is the problem of overcapacity and low profit margins for petrochemicals and other commodities. An industrywide capacity reduction program, sponsored by the Brussels-based Association of Petrochemicals Producers in Europe, fell by the wayside late last year, so companies have been faced with taking unilateral action, if any, to reduce capacity.

At the beginning of this year, BP Chemicals closed its ethylene cracker at Baglan Bay in Wales. "Further industry restructuring is needed, but our remaining petrochemical assets are among the most efficient in Europe," says Sanderson. "It was a painful restructuring for BP, but it was certainly the right thing for us to do. We would have preferred, of course, to have it part of a European industrywide restructuring. That will still have to be done, eventually.

"It was a tough year, really," he adds. The operating loss of $102 million carried over from an operating loss of $35 million the year before, because "historically low petrochemicals margins in Europe" were only partly offset by productivity improvements, cost savings, and favorable exchange rate movements. A higher level of restructuring costs also added to the operating losses.

BP Chemicals' cracker closure was a lonesome action. Tony Church, chemicals analyst with London stockbrokers Wertheim Schroder & Co., points out, "There has been no significant change in the amount of capacity that will be available in Europe over the next two or three years. Taken together with the ongoing effects of the European recession, we believe that the failure to reduce capacity ensures that restoring margins when the economic upturn does occur is going to be very difficult."

Moreover, he adds, "Our latest information is that, although the climate is changing to a greater acceptance by customers of higher feedstock costs, large price rises by chemical producers seem unlikely against continuing oversupply."

However, the picture is slowly becoming clearer and brighter. For instance, at the press conferences held last month to reveal 1993 annual results, executives for Germany's big three chemical firms—Hoechst, BASF, and Bayer—were all optimistic, even though the German economy is still among the most depressed among European countries.

Normally, the yearly spring press conferences for the three companies are solemn two-hour question-and-answer marathons. This year, however, Manfred Schneider, chairman of Bayer, for example, was in good enough spirits to pepper his press conference with puns and jokes. But then, improved conditions gave him some justification. Pessimistic predictions a year ago about severe earnings drops did not come to pass, except in Europe, where Bayer's operating earnings dropped 31%. Growth elsewhere—in North America, for example—cushioned the impact, limiting the company's total fall in profits.

More encouraging, however, was that "the fourth quarter of 1993 was better than anticipated, and sales in January and February 1994 rose by more than 6%," to nearly $4.12 billion, according to Schneider.

Two months do not make a full year, of course, and company executives have been cautious about extrapolating corporate results for 1994 based on January and February, and possibly a strengthened fourth quarter of 1993. Many are now agreeing, however, that things are picking up.

"Chemicals outperform the market at the bottom of cycles and in the first year of the recovery in the cycle," observes Kleinwort Benson's Cox. "We are looking for anything from a 10 to 40% increase in chemical profits this year—but that is from a very low base. Earnings as an absolute value won't be satisfactory, but it will be solid growth." ☐

Firings, Outlook Worse For Long-Time Workers

The Subcommittee on Professional Standards & Ethics of the former ACS Committee on Professional Relations' (CPR) latest report on multiple terminations gives details of six such terminations that occurred between April 1991 and January 1993. These terminations involved 56 job losses by chemical professionals.

CPR went out of business at the end of 1993 when it and the ACS Committee on Economic Status were merged into the Council Committee on Economic & Professional Affairs (CEPA).

The report, the 37th in a series dating back to 1974, indicates that an additional five multiple terminations have been verified and 21 as yet unverified reports are currently under investigation.

A multiple termination, as defined by CPR guidelines, is a situation in which the employment of three or more chemical professionals is terminated by a single employer within a six-month period for reasons other than continuing evidence of previously documented inadequate performance, completion of a contract, or cause.

The reports have always been concerned only with job losses that are clearly involuntary. They do not provide a mechanism for investigating the "voluntary" separations and early retirement programs that have pervaded the chemical and related industries in recent times. Thus, the reports may not accurately reflect the employment picture for some chemical professionals.

There have also been numerous problems gathering information from terminees and from employers. For these and other reasons, CEPA voted to phase out this multiple termination program at the end of 1994. The committee will, however, complete pending investigations and monitor and publish employment information via other means.

The six multiple terminations detailed in the latest report were at Aluminum Co. of America (Alcoa), Amoco Petroleum Additives, Ethyl Corp., Georgia-Pacific, Koch Protective Treatment Inc., and S.C. Johnson Wax. The largest was at Ethyl, with 21 confirmed involuntary separations; the smallest was at Koch, with three.

The five verified multiple terminations on which CEPA investigations are not yet complete were at Miles Diagnostic, Koch, A. D. Little, Dow Chemical, and UOP.

As is customary, the latest report compares the performance of employers with standards spelled out in ACS's Professional Employment Guidelines (PEG). These guidelines are concerned with advance notice, severance pay, assistance in finding new employment, length of employee service, and employee protection after termination.

Overall compliance with the PEG standards has remained fairly constant over the years. For the first 19 reports, through mid-1984, compliance was 42%; since then, it has been 44%. For this report, it was 42%.

The most discouraging news comes in the drop in compliance in meeting employee service standards. PEG standards call for no terminations of employees who have 10 years' or more service. For the first 19 reports, compliance was 26%; since then, it has dropped to 13%. No employers in the current report complied with standards in this category. About 60% of all terminees in the current report appear to have had more than 10 years of service; among these, the average length of service was 21 years.

Employer compliance with ACS employment guidelines

These employers provided information	Number of confirmed separations	Advance notice	Severance pay	Assistance	Employee service	Protection plans
Ethyl Corp. (Baton Rouge, La.)	21	☐	▨	☐	▨	▨
S. C. Johnson Wax[a] (Racine, Wis.)	5 / 0	☐	☐	☐	■	☐
This information was received from employees						
Aluminum Co. of America (Alcoa Center, Pa.)	6	☐	☐	☐	■	▨
Amoco Petroleum Additives (Naperville, Ill.)	12	▨	☐	☐	■	☐
Georgia-Pacific (Port Edwards, Wis.)	9	☐	▨	☐	■	■
Koch Protective Treatment inc. (Dayton, Ohio)	3	■	▨	■	■	▨

[a] This reflects the contradictory information provided by the company and the employees. The company reported no involuntary terminations; five employees reported they were involuntarily terminated.

☐ Employer met or exceeded guideline standard.

▨ Two or more individuals below guideline standard, but average experience better than "substantially below" criterion.

■ Employer was substantially below guideline standard, which is defined as follows:

- Advance notice—less than four weeks.
- Severance pay—less than two weeks per year of service.
- Assistance—no assistance rendered.
- Employee service—more than 30% of terminees had 10 or more years of service.
- Protection plans—no continuation of protection plans.

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ACS Professional Employment Guidelines

- **Advance notice.** Four-week minimum.
- **Severance pay.** Minimum is two weeks per year of service. Additional notice may be given, by mutual agreement, in lieu of severance pay.
- **Assistance.** Efforts should be made to place terminee in another position within the organization, or terminee should be given assistance to find employment elsewhere.
- **Employee service.** Those with minimum of 10 years' service should not be terminated except for continued evidence of previously documented inadequate performance or cause.
- **Employee protection plans.** Should be extended for a minimum of one month, plus two weeks for each year of employee service, following termination, at same rate of contribution as before. Employee would have additional 31-day grace period.

These data were somewhat offset by evidence of improvement in meeting the severance pay standard of two weeks' pay for each year of service. For the first 19 reports, only 16% of employers complied. For the second 18, compliance was 42%. This report indicated 50% compliance.

Also showing improvement was compliance with PEG standards that call for four weeks' advance notice of termination. In the latest report, four of six employers—Ethyl, S.C. Johnson Wax, Alcoa, and Georgia-Pacific—complied with this standard. One, Amoco Petroleum Additives, fell below guidelines. Koch fell substantially below guidelines. Throughout the years, compliance with this standard has remained steady at about 40%.

Compliance with the employee assistance standard has improved throughout the years, dropping only slightly to 83% for this report. The first 19 reports indicated 65% compliance; since then, compliance has risen to 86%. In the current report, only Koch failed to offer terminees résumé preparation and other services.

The PEG standard on protection plans calls for continuation of health insurance at employer expense for at least one month beyond separation. Compliance, 48% over the past 20 years, has declined over the past 10 years to 34%. The figure for the current report is 33%. Under the Consolidated Omnibus Budget Reconciliation Act of 1985, however, a terminee is entitled to continuation of benefits for up to 18 months. This may be the primary reason that employers appear to be falling short on meeting this guideline.

Chemical professionals who have been fired or have taken early retirement are requested to contact the American Chemical Society, Office of Professional Services, 1155—16th St., N.W., Washington, D.C. 20036. Copies of all multiple termination reports and related C&EN stories are available, on request, from the same office.

Linda Ross

Lehigh Valley Section's 100th anniversary

The ACS Lehigh Valley Section celebrated its 100th anniversary last month. A full-day program in Bethlehem, Pa., included the dedication of Lehigh University's William H. Chandler Chemistry Laboratory as the second ACS National Historic Chemical Landmark, two centennial lectures, and a dinner dance.

The section was launched a century ago when 15 chemists gathered at the Chandler Lab. The goals of the new section were to advance chemical science and to improve science education in the Lehigh Valley area. Today, the section's membership includes nearly 1,000 chemists, chemical engineers, and educators. Members are drawn from 97 local companies, 11 area colleges and universities, and seven high schools.

As part of the anniversary program, centennial lectures were given by Lehigh University professor emeritus Roland W. Lovejoy, and chemistry department chairman Kamil Klier. The lectures highlighted the development of infrared and photoelectron spectroscopy. Afterward, local industrial representatives displayed exhibits highlighting their progress during the past century.

Later, more than 150 members of the section gathered to celebrate and to hear ACS president and Lehigh University professor Ned D. Heindel deliver the Centennial Address, "Showcasing Chemistry: The ACS Smithsonian Exhibit."

Photo by J. H. Lerch, Air Products

Gilicinski (left) and McHale at centennial celebration.

During the program, section chairman Andrew Gilicinski presented Heindel with the section's 1994 Service Award, its highest honor.

Attila Pavlath, ACS director-at-large, was on hand to present special certificates to all past chairmen in attendance. Fifty-year section members were also recognized. Attendees included Rep. Paul McHale (D.-Pa.), ACS executive director John K Crum, and ACS Board chairman Paul H. L. Walter. ☐

Vacancies to be filled

Two vacancies have been created on the ACS Council Committee on Nominations & Elections (CN&E) by the recent resignations of Stanley H. Pine, who resigned to accept an appointment to the Society Committee on Education, and Henry F. Whalen Jr., who resigned to become a candidate for director-at-large this fall. A special election will be conducted by mail ballot among ACS councilors to fill the vacancies. The Council Policy Committee has selected Warren V. Bush, George E. Heinze, Alvin L. Kwiram, and Kathleen Trahanovsky as candidates.

Other candidates may be nominated by petition; signatures of at least 25 councilors are required for a valid petition, and petitions must be received by the ACS executive director by May 31. Ballots will be mailed to councilors in time to have the new CN&E members seated at the fall meeting in Washington, D.C. In accordance with ACS bylaws, the successful candidates will serve the remainder of the terms of Pine and Whalen.

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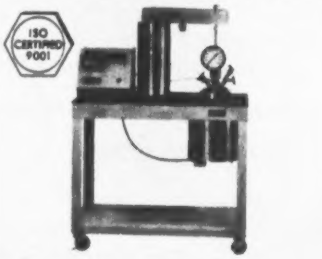

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APRIL 18, 1994

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SCANNING TUNNELING MICROSCOPY

Surface technique provides insights on internal structure of layered solids Page 28

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CHEMICAL & ENGINEERING NEWS

C&EN

APRIL 18, 1994

NEWS OF THE WEEK

- University of Kentucky researchers propose a new mechanism for Alzheimer's disease—that the nerve cell damage is caused by free radicals generated from the breakdown of β-amyloid peptide. **Page 4**
- A catalytic route to directly convert methane to acetic acid has been developed by Penn State chemists. **Page 5**
- 3M, Union Carbide, and three small companies agree to join the global silicone breast implant settlement. **Page 5**
- A program is launched to increase the number of blacks working toward doctorate degrees, especially in science and engineering. **Page 6**
- The Army tells Congress it plans to continue to implement its $9 billion incineration program to destroy the U.S.'s stockpile of chemical weapons, calling alternative technologies incapable of meeting requirements. **Page 7**
- House subcommittee renews its scrutiny of scientific misconduct, members charge scientific community with inadequate responses to fraud in cancer study. **Page 7**

COVER: Computer-graphic image of the surface of a thin-film, high-T_c superconductor generated by Melvin L. Prueitt, Los Alamos National Lab, using STM data supplied by Marilyn E. Hawley, Ian D. Raistrick, and Jerome G. Beery

Volume 72, Number 16
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BUSINESS

Polyethylene terephthalate resins are continuing double-digit growth in bottle and other package markets, but producers are feeling the pressure to develop new grades of the plastics and to invest in new capacity. **Page 11**

GOVERNMENT

Chemical weapons treaty is endorsed by experts, though some are concerned about meeting the tight deadline for ratification and passage of enabling legislation. **Page 16**

SCIENCE/TECHNOLOGY

Oligonucleotide analogs show promise as antisense agents—which bind to and inhibit nucleic acids—demonstrating increased resistance to nucleases and higher affinity for targets. **Page 21**

Development of catalyst systems for industrial processes plays a key role in designing environmentally benign chemical processes. **Page 22**

Theoretical and experimental evidence supports one of two long-standing models for solvent kinetic isotope effects. **Page 25**

Chemists use a nonnatural amino acid to make a peptide with improved biological activity and degradation resistance. **Page 26**

Improved catalysts are described for coupling of methane and reduction of nitrogen oxides in flue gas. **Page 27**

MEETINGS

ACS 24th Northeast Regional Meeting, June 19-22, in Burlington, Vt., will feature 250 presentations. **Page 49**

SPECIAL REPORT

Scanning tunneling microscopy, a powerful analytical tool that provides a real-space view of the atomic structure and electronic states of a solid, yields information about detailed physics of materials in a language that chemists can understand. Page 28

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LETTERS

Organochlorine drugs

As a naive, occasional beneficiary of pharmaceutical drugs, I have a simple question to ask: What will happen to the dozens of chlorine-containing medicines if chlorine and all chlorinated chemicals are summarily banned becase of suspected toxicity of a few organochlorines—as is being proposed by Greenpeace, the Environmental Defense Fund, and assorted environmental juntas? Does Greenpeace have substitutes for Claritin, Ultravate, Elocon, Mepron, Almide, Wellbutrin, Femstat, Lopidine, Selepam, Melex, Bonefos, Aclovate, Fareston, Proendotel, Propulsid, Halfan, and Sporanox—all of which contain chlorine.

These specific organochlorine pharmaceuticals are used to treat millions of Americans annually for depression, arthritis, fungal diseases, glaucoma, inflammation, psoriasis, allergies, infections, osteoporosis, ulcers, malaria, coronary disease, and cancer. What will happen to the millions of American children who develop severe middle-ear infections and are now best treated with the chlorine-containing antibiotics Ceclor and Lorabid if these drugs are banned?

Of the nearly 400 new drugs approved for therapeutic use in humans since 1984, more than 60 are organochlorine compounds. Two of the 10 most prescribed pharmaceuticals, Ceclor and Xanax, contain chlorine. How does Greenpeace plan to replace the dichloro-containing vancomycin—the only antibiotic effective against hospital staph infections? Or Losartan, the new DuPont-Merck drug for hypertension, or the two clinical candidate drugs CI-1002, the Parke-Davis agent for Alzheimer's disease, and NE-10064, the new Procter & Gamble antiarrhythmic drug? All of these are organochlorine compounds and are perfectly safe.

Gordon W. Gribble
Department of Chemistry
Dartmouth College
Hanover, N.H.

Literacy is already defined

Frank X. Sutman (C&EN, March 28, page 2) accuses James Trefil (C&EN, March 14, page 26) of scientific elitism for suggesting that the public should be better informed on matters scientific. Not to be outdone, Sutman then proceeds to rewrite the dictionary on the definition of literacy, surely an elitist maneuver if there ever was one.

Literacy, the state of being literate, has (at least up to this time) meant the ability to read, write, and presumably to understand what was written or read. Literacy as a "willingness to learn" is just the sort of dumbing down that is going on in the schools today. Equal weight cannot be given to knowledge attainment and attitude development without hopelessly confusing the educational process. The plain facts are that most high school graduates have a good attitude but can't write a simple descriptive paragraph. This means that they are illiterate and no level of redefinition can change that.

James A. Gallagher
Grosse Ile, Mich.

Benefits of eye protection

Letters to the editor by Jay A. Young and John M. Hoffman (C&EN, Feb. 7, page 3) deal with legalities that do not require the wearing of eye protection "when nothing dangerous is going on." A followup by Malcolm M. Renfrew (C&EN, March 21, page 2) noted the liability of management should an accident happen in a supposedly non-accident-sensitive laboratory situation. I would like to address the potential "victim's" perspective.

As a graduate student at Brooklyn Polytech, many years ago, I was in the process of scraping out a crystalline precipitate from the bottom of a beaker, using a glass rod to dislodge the precipitate. A nonhazardous situation? I have never felt dressed in a laboratory without my safety glasses. Fortunately, my glasses were right where they were supposed to be.

The precipitate was unyielding and the glass rod broke in half, the bottom end tumbling upward, end over end, with considerable force. The broken end of the rod directly impacted, end on, onto one eyeglass face with such force that my head was jarred backward. Fortunately, the glass lens held intact and I was spared who knows what pain, heartache, and anguish. Don't tell me there are situations in the laboratory "when nothing dangerous is going on."

Patrick V. Bonsignore
Argonne National Laboratory
Argonne, Ill.

Correction

- April 4, page 9: Enzon's net loss for the fiscal year ending June 30, 1993, was $24.6 million, not $78.9 million, which is the company's cumulative loss since its inception in September 1981.

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tlement is joined by General Electric, which supplied silicone materials to implant makers, and by some smaller suppliers.

Judge Sam C. Pointer Jr. of the U.S. District Court of Alabama in Birmingham must give preliminary approval to the five companies' settlement offers. Pointer must then notify women affected by the settlement and hold a fairness hearing, after which he may give his final approval. Pointer has jurisdiction over all federal breast implant suits.

Of the five firms, 3M will make the largest contribution, $325 million. The diversified chemicals and materials manufacturer owned McGhan Medical Corp., a small manufacturer of breast implants, between 1977 and 1984. In March, a Houston jury ordered 3M and McGhan to pay about $30 million in a breast implant lawsuit (C&EN, March 14, page 8). But a 3M spokesman calls it a coincidence that the company is joining the settlement so soon after it lost the suit. McGhan also will join, contributing $25 million.

Union Carbide will make the second largest contribution of the five firms, $138 million. It did not make implants but supplied what it calls generic bulk silicone materials to the industry. Two other small silicone materials makers will join the settlement: Wilshire Foam Products (providing $8 million) and Applied Silicone Corp. ($225,000).

Marc Reisch

Program aims to boost number of black Ph.D.s

A new program designed to increase the number of blacks working toward doctorate degrees—especially in science and engineering—was announced at a press conference in Washington, D.C., last week by the National Association of State Universities & Land-Grant Colleges (NASULGC) and the American Association of State Colleges & Universities (AASCU).

A key element in the National Minority Graduate Feeder Program is to identify promising undergraduates in their junior and senior years at 38 historically black public colleges and universities and to enter their names into a national computerized database. Launched with a $119,000 grant from the General Electric Foundation, the database will match these outstanding students with doctoral degree-granting universities that are members of NASULGC and AASCU. These two organizations have more than 500 institutions eligible to participate; the first-year goal is to enlist at least 20 to 30 schools in the program.

Each institution must agree to establish 10 Ph.D. fellowships or teaching assistantships specifically targeted to these students. Schools also will be required to identify faculty members to implement and monitor the program on campus, to ensure that proper mentoring takes place.

"Our goal for the first full year of the program is to identify as many as 700 students majoring in engineering, computer science, chemistry, biology, physics, and mathematics," says Frederick S. Humphries, president of Florida A&M University and chairman of the board of directors of NASULGC.

"By drawing from this pool, before too long we should be able to change [a] disgraceful fact," Humphries stresses: In 1992, American universities awarded just 13 Ph.D. degrees in chemistry to black U.S. citizens (out of more than 2,000 chemistry doctorates); only seven Ph.D.s in physics and astronomy; four each in mathematics and computer science; and six in earth, atmospheric, and marine sciences. Even more alarming, the Florida educator adds, is that the number of blacks earning Ph.D.s declined between 1991 and 1992.

Humphries, a physical chemist, has long contended that the extreme underrepresentation of blacks in U.S. graduate schools reflects a lack of university leadership (C&EN, Sept. 13, 1993, page 48). Although no financial goals have been set for the program, Humphries says, "We decided not to say we needed $7 million or $10 million to start acting. The problem is too important to wait." When fully operational, the program plans to raise money from corporations and philanthropies to provide fellowships to juniors and seniors to help support them prior to graduate school.

Several university presidents praise the new program. Typical is the comment of Purdue University president Steven C. Beering: "Because this proposal brings together the collective force of two major associations and ... some of our nation's very strongest graduate education programs, it has the potential to impact minority groups more than any single institution or geographically linked consortia of universities may be able to do."

At a minimum, the database will contain information on a student's academic discipline, grade point average, and Graduate Record Exam scores that can be accessed by participating universities. "Most of these schools also have summer research programs for undergraduates," explains Humphries, "and we anticipate that a lot of these universities will use the database to get an early 'look-see' at the most promising students."

Madeleine Jacobs

C&EN staff photo

Humphries: to change a disgraceful fact

Number of doctoral degrees in the sciences received by blacks remains low

Black doctorates[a]	1992	1991	1990	1980	% change 1991–1992
Total, all disciplines[b]	961	1,003	898	1,031	–4.2%
Physical sciences	34	40	27	25	–15.0
Chemistry	13	18	14	10	–27.8
Engineering	32	43	28	11	–25.6
Chemical	8	4	4	0	100.0
Life sciences	87	88	73	65	–1.1

a Includes U.S. citizens only. b Includes physical sciences, engineering, life sciences, social sciences, humanities, education, and professional (other fields). **Source:** National Research Council, "Survey of Earned Doctorates, 1992"

PET Resins Maintain Strong Growth Despite Market Challenges

■ ***Producers of widely used plastic for bottles face increasing pressure to develop new grades and add capacity***

Susan J. Ainsworth, C&EN Houston

Polyethylene terephthalate (PET) resins have been a bright spot in the plastics business, which has generally been in the doldrums over the past few years.

In particular, the 2.1 billion-lb-per-year merchant market for PET resins in the U.S., which includes sales of PET resin to customers who make final products like bottles and thermoformed trays, is growing at a rate of 11.5% per year, according to Terry L. Persinger, general manager for PET at Shell Chemical in Houston.

Demand for PET resin has remained high since the plastic first appeared on the market in 1977, says Persinger, simply because "it makes a great package. The carbonated soft drink market continues to grow, especially in single service sizes as consumers look for the convenience and recyclability of bottles made from polyester resins. The lightweight, shatter-resistance, and heat-stability benefits of polyester containers have also increased the demand for bottle-grade resins in containers for noncarbonated beverages and other foods."

Although producers of PET resins are enjoying strong demand for their products, the market is not without its challenges. To sustain long-term growth in use of PET-type containers, producers are under pressure to develop new grades of PET to meet changing packaging needs. At the same time, they are pressed to keep up with demand by investing in capacity expansions. In fact, five companies are slated to bring on more than 1 billion lb of new PET annual capacity by the end of 1996. Persinger calls all of these expansions "essential" and expects that they will keep supply and demand in balance through 1997.

Two months ago, Shell began engineering design work for a possible expansion of its Point Pleasant, W.Va., polyester resins plant. Pending approval by mid-1994, the 165 million-lb-per-year expansion is expected to be completed by the end of 1996, says Persinger. "This expansion is necessary for Shell Chemical to support this market, which is seeing a significant increase in demand for polyester resin."

The Point Pleasant plant, with current capacity of 450 million lb annually, is already in the process of completing another 155 million-lb-per-year expansion slated to go on stream this month. Last year, Shell entered into a long-term agreement under which it could purchase up to 120 million lb per year of precursor bottle resin from Wellman, a plastics manufacturer and recycler based in Shrewsbury, N.J. Shell will begin to purchase the resin in mid-1995 after Wellman starts up a new 160 million-lb-per-year PET resin line at its Darlington, S.C., polyester fiber and resin production facility.

Five producers plan to add over 1 billion lb of PET capacity by 1996

Company/location	Annual capacity (millions of lb)	Startup year
Shell Chemical		
Point Pleasant, W.Va.	155	1994
Point Pleasant, W.Va.	165	1996
Eastman Chemical		
Cosoleacaque, Veracruz, Mexico	140	1995
Nan Ya Plastics		
Lake City, S.C.	238	1995
Hoechst Celanese		
Queretaro, Mexico	150	1994
Wellman		
Darlington, S.C.	80	1994
Darlington, S.C.[a]	160	1995

[a] About 120 million lb of precursor bottle resin to be produced for Shell Chemical by Wellman. **Source:** Individual companies

Separately, just last month, Wellman began producing about 80 million lb per year of PET resin for packaging applications at its polyester staple fiber and resin production facility at Darlington. This expansion, planned before the Shell agreement, brings total packaging resin capacity to about 200 million lb per year at the site.

A newcomer to the market, Nan Ya Plastics, a Livingston, N.J.-based subsidiary of Formosa Plastics Group, headquarted in Taipei, Taiwan, plans 238 million lb per year of PET capacity at Lake City, S.C., by August 1995. according to J. S. Tseng, assistant vice president of Nan Ya Plastics.

In addition, two companies are currently building PET plants in Mexico. Although much of the capacity likely will go to supply the growing market for soft drink bottles there and in South America, Persinger expects that about half of the production will be supplied to the U.S. market.

Hoechst Celanese is expected to bring on 150 million lb per year of PET packaging resin capacity at its existing plant at Queretaro, Mexico, during the second quarter of this year. The company targeted Mexico for the plant because it is a high-growth market and one in which Hoechst Celanese is already a major supplier, says Lewis R. Morrison Jr., director of the PET resins business unit within Hoechst Celanese's fibers and film group in Charlotte, N.C.

Sometime in the middle of this year, Eastman Chemical, Kingsport, Tenn., expects to begin construction of a new 140 million-lb-per-year PET bottle polymer plant at the Tereftalatos Mexicanos (Temex) plant site in Cosoleacaque, Veracruz, Mexico. The plant is scheduled to start up in late 1995. East-

Amoco Chemical's Gupte holds NDC copolyester bottle; others on table are based on PEN.

man and Grupo Industrial Alfa, Temex's majority owner, formed an alliance to bring the project together. Eastman will own the PET plant and will be responsible for its operation; Temex will supply purified terephthalic acid (PTA), the primary raw material for PET, as well as utilities and some services. "With the PET plant located at the Temex site, both companies will gain significant efficiencies," says Harry H. Holliman, vice president and general manager of Eastman's Container Plastics business organization.

Holliman says Eastman's decision to build a PET plant in Mexico was influenced by the potential of the Mexican and other Latin American markets, efficiencies associated with locating at the Temex site, and the improving investment climate in Mexico. Mexico is the world's second largest soft drink market after the U.S. In 1991, the PET refillable soft drink bottle was introduced in Mexico and has enjoyed substantial growth. Eastman has developed a polyester for a refillable bottle and projects that a significant portion of the new plant's output will be directed toward this application throughout Latin America.

It's not hard to see why demand for PET is so strong. Used as a packaging material for soft drink bottles and custom bottles, PET is tough to beat. One of its greatest attributes is that it has a proven track record for being recycled, which is important considering more than 38% of all soft drink bottles and more than 28% of all PET containers were recycled in 1992, according to Persinger. The custom bottle and soft drink bottle markets together are expected to generate growth of 11% or so, representing an increase of 1 billion lb in the five years between 1993 and 1998.

Persinger also expects to see growth in demand for crystallizable PET. Crystallization increases the heat resistance of PET in addition to turning it opaque, making it well suited for use in conventional convection ovens as well as microwave ovens. It also can be handled by high-speed packing and freezing equipment at below –40 °F without breakage. In addition, Shell is developing a low-density crystallizable PET product that will take advantage of PET's performance and reduce costs and weight.

Amorphous PET, which is designed for extrusion into unoriented, clear sheet using conventional thermoplastic extrusion methods, is also quickly becoming the product of choice for drinking cups, deli packaging, and baked goods packing, says Persinger. Crystallizable PET and amorphous PET markets together will grow from about 180 million lb in 1993 to about 300 million lb in 1998, he predicts.

Although PET resins are now used in a number of packaging applications, producers must continue to adapt their product to meet the changing demands of the market. For example, PET producers are facing new challenges resulting from growing demand for 12-, 16-, and 20-oz single service PET bottles, which are smaller than the 2- or 3-L traditional PET bottles. These bottles require faster cycles and very consistent polymer properties at low cost to compete in this highly competitive market. Persinger says Shell is continually improving its proprietary polymer process design to improve resin uniformity.

Much of the long-term growth in PET-type containers lies with the successful development of improved grades for oxygen permeability and thermal stability for hot-fill applications, which is one of the hottest growing packaging segments, says Persinger.

By coupling the latest equipment technology for heat setting with resins designed to set quickly, PET can now be used to package foods filled at up to 190 °F. For example, ketchup is now being packaged in bottles using a small amount of ethylene-vinyl alcohol sandwiched between layers of PET to improve gas barrier resistance by inhibiting oxygen permeation.

In the future, a new monomer called naphthalene dicarboxylate (NDC) will be used in conjunction with PET to produce a polymer with higher barrier and heat resistance. Chicago-based Amoco Chemical is the only company in the world building a commercial facility to produce NDC. Startup is anticipated at its Decatur, Ala., site during the first half of 1995.

NDC can be used to enhance PET's properties two ways, says Janine S. Gupte, product manager for NDC at Amoco Chemical. It can be reacted as a copolymer with dimethyl terephthalate, a possible raw material for PET production, to produce a resin with better barrier and heat resistance properties than PET. And NDC can be polymerized to make polyethylene naphthalate (PEN), which can then be blended with PET to improve PET's properties, she adds.

Currently, Amoco Chemical and Shell Chemical are jointly seeking regulatory clearances for these NDC-based polyesters of commercial interest. In their view, regulatory clearances are a critical milestone for the acceptance of high-performance polyesters in packaging applications.

Gupte says PET producers have been excited about the prospect of buying commercial quantities of NDC, and she anticipates that "in the near future, companies will begin to make serious plans" to use this material to enhance their packaging product portfolios.

Ed Paschke, a research associate at the Amoco Research Center, Naperville, Ill., who has been working with PEN since 1986, says, "PEN extends the limits of polyesters, improving performance for existing applications while making polyesters desirable in entirely new applications." For example, PEN's higher thermal resistance means that a PEN baby food jar could withstand the retort packaging process in which containers are steam sterilized. Because PEN jars are nonbreakable, unlike the glass jars in which baby foods are now packaged, they also eliminate a common safety concern, he says.

If the PET resin market is to continue to enjoy double-digit growth annually, producers will have to face up to significant challenges, Persinger says. "New competition and capacity are entering the U.S. market, but if growth continues as expected, supply and demand should stay in balance. That should help make PET the packaging resin of choice for food, beverages, and other household containers." ☐

CHEMICAL & ENGINEERING NEWS
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ISO 9000

Chemical industry takes active role in developing international management standards

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CHEMICAL & ENGINEERING NEWS

C&EN

APRIL 25, 1994

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- Chemists at Boston College develop a molecular "brake," involving a side chain that reversibly slows down a triptycene "wheel." Page 6
- A new semiconductor laser, the quantum cascade laser, which can be tailored to emit light of any frequency in the mid- to far-IR range, has been developed by AT&T Bell Labs scientists. Page 7
- Industrial release of toxics into the U.S. environment fell in 1992 for the fifth straight year, but waste generation rose slightly. Page 8
- Sales of Monsanto's bovine growth hormone are booming, despite attacks on its use from lawmakers and consumer and environmental activists. Page 8
- Top executives from seven tobacco firms reject charges of nicotine manipulation and research suppression at a House hearing. Page 9
- Danish producer Novo Nordisk opens what may be the largest multipurpose enzyme plant in North America. Page 9

COVER: Photo by Uniphoto Picture Agency

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BUSINESS

Cytec Industries' chairman Darryl Fry strives to create "cultural discontinuity" in the newly independent chemicals company and to establish the firm in the commodity and specialty sectors. Page 29

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Predicted effects of fixed or shrinking research budgets on federal labs, universities, and researchers are now realities, dictating that changes be made in how science is done. Page 35

Current U.S. global-change research program will not provide decisionmakers with the information needed to respond to global change, say speakers at a symposium. Page 39

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Canadian researchers report finding the enzyme telomerase in cancer cells but not in healthy cells, suggesting that its inhibitors could be effective anticancer drugs. Page 42

Construction has begun on a new laboratory at Hanford and on a 1,000-MHz NMR system that will be a centerpiece in the facility, which will focus on environmental restoration. Page 44

EDUCATION

NOBCChE, an organization for black chemists and chemical engineers, is changing—expanding its membership base, adding to its student chapters, and broadening its activities. Page 47

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Program of the 49th ACS Northwest Regional Meeting includes more than 150 invited and contributed papers in 14 symposia and workshops ■ Graduate Research Polymer Conference to be held in June at Penn State University will provide a forum for graduate students. ■ National Chemical Information Symposium to be held in Vermont in June will feature interactive sessions. Page 49

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Chemical companies are seeing beneficial results from ISO 9000 registration as the international standards become a basic component of quality management and evolve rapidly in the environmental arena. Page 10

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LETTERS

CHEMICAL SAFETY

Potential hazard in hydrosilylation of D_4^{Vi} with D_4^{H}

We would like to comment on a recent communication by M. J. Michalczyk, W. E. Farneth, and A. J. Vega in *Chemistry of Materials* [5, 1687 (1993)]. In this paper, one of us describes a synthesis of highly cross-linked carbosiloxane glasses by hydrosilylation of $[(Me(Vi)SiO)_4]$ (D_4^{Vi}) and $[(Me(H)SiO)_4]$ (D_4^{H}) according to the procedure described in the General Electric patents by H. F. Lamoreaux. In all preparations of these glasses at DuPont, no safety problems or unusual hazards were observed in carrying out the hydrosilylation reaction D_4^{Vi} with D_4^{H}.

However, recent communication between us has brought to our attention some potential safety hazards associated with this synthesis. In particular, researchers at General Electric have sometimes observed uncontrollable exotherms or explosions during the hydrosilylation of D_4^{Vi} with D_4^{H}. Exothermic reactions were also observed when an excess of D_4^{H} was used. At DuPont, we have observed similar exotherms during the hydrosilylation of tetravinylsilane with D_4^{H}. Because of the potential safety problem associated with this and other related syntheses, we now suggest caution be used when carrying out the hydrosilylation reaction of D_4^{Vi} with D_4^{H} and recommend that hydrosilylations using monomers with low flash points be carried out behind a safety shield at the smallest possible scale with a low level (below 20 ppm) of platinum. The typical commercial product lines that employ platinum cures have no hazards.

Slawomir Rubinsztajn
Larry N. Lewis
Judith Stein
General Electric Corporate R&D
Schenectady, N.Y.
Michael J. Michalczyk
DuPont Central R&D
Wilmington, Del.

Phase-transfer catalysis

I read with interest the meeting brief (C&EN, March 28, page 43) that reports phase-transfer catalyzed reactions in supercritical fluids and suggests that this is the first work of the sort to have been performed. It is worth noting that phase-transfer catalyzed reactions have been previously carried out in environmental analytical chemistry applications. Phase-transfer catalysts have been used with supercritical fluid extraction (SFE) to simultaneously derivatize and extract organic chemicals from environmental matrices.

Two reports document the derivatization of chlorophenoxy acid herbicides by phase-transfer reactions under in-situ SFE conditions. Last year, Viorica Lopez-Avila and coworkers formed the pentafluorobenzyl derivatives of several chlorophenoxy acid herbicides using pentafluorobenzyl bromide and triethylamine as the catalyst [*J. Agric. Food Chem.*, **41,** 2039 (1993)]. Earlier this year, Richard J. Wells of the Australian Government Analytical Laboratories reported to the 5th International Symposium on Supercritical Fluid Chromatography & Extraction on the use of tetrahexylammonium hydroxide with methyl iodide for the in-situ derivatization of 2,4-D from water immobilized on a solid support. Quaternary ammonium ion pair reagents were used initially in SFE, in the absence of an additional electrophilic alkylation reagent, for the extraction and derivatization of microbial phospholipid fatty acids from whole cells of *Escherichia coli*, chlorophenoxy acid herbicides from soils and sediments, and aliphatic and aromatic sulfonated surfactants from sewage sludges (Steven B. Hawthorne, et al. [*Anal. Chem.*, **64,** 405 (1992)] and Jennifer A. Field, et al. [*Anal. Chem.*, **64,** 3161 (1992)]). Clearly, quaternary ammonium ion pair reagents and other phase-transfer catalysts show tremendous potential for application in chemical engineering and environmental chemistry.

Jennifer A. Field
Department of Agricultural Chemistry
Oregon State University
Corvallis

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NEWS FOCUS

Chemical Companies See Beneficial Results From ISO 9000 Registration

International standards have become a basic component of quality management and are evolving rapidly in the environmental arena

Ann M. Thayer
C&EN Northeast News Bureau

ISO 9000 standards have taken force worldwide. Although ISO 9000 standards are just five among the thousands of standards issued by the 48-year-old International Organization for Standardization (ISO), their impact cannot be ignored. This year, updated and slightly modified ISO 9000 standards are expected to be published. By the end of the decade, more significant changes—to broaden concepts and update the standards relative to marketplace and technology needs—are anticipated.

Although there will be some effect from these changes, even bigger events are in the making. In June 1993, ISO created Technical Committee 207 (TC 207) to begin work on new standards for environmental management systems (EMS). The standards' ramifications worldwide, and to the chemical industry, which has become heavily involved in their development, will be great. TC 207's activities are being scrutinized closely and will continue to be into 1995 when the first environmental standards are expected to be published.

Companies with ISO 9000 guidelines already in place probably can expect to see similarities in the new standards for EMS. The ISO 9000 series, first published by the Geneva-based ISO in 1987, consists of five generic standards, which provide only guidance—and not prescriptive performance limits—for companies in establishing quality management systems. Key to the process is not just the setting up of a system, but also the thorough documentation of a company's operations.

Once thought to be of primary importance for access to the European market, ISO 9000 standards also are serving as a baseline process through which companies respond to customers and document internal quality programs. More than 70 countries have adopted the ISO 9000 series for use as national standards; thousands of organizations, including government agencies, are using the voluntary standards. In the U.S. and Canada, the number of ISO 9000 registrations reached about 3,600 in the first quarter of 1994, a jump from about 1,500 a year ago and from about 400 two years ago, according to CEEM Information Services, Fairfax, Va.

The chemical industry leads all other industries in the U.S. in gaining ISO 9000 certification, according to CEEM, with chemical companies now accounting for more than 600 registrations or about 19% of total U.S. registrations. The most common registrations in the chemical industry are to ISO 9002, which covers quality systems and assurance in manufacturing and in the delivery of a product, but does not cover design. In a C&EN survey of 38 companies, including 36 major chemical producers and two engineering firms, companies gave their views on the impact of ISO 9000 standards on company operations.

It was only a few years ago that most U.S. chemical companies began registering their operations to one of the ISO 9000 standards. Having taken root largely in Europe, ISO 9000 standards registration often was first sought by overseas operations of U.S. companies or by foreign companies. Now, many U.S. companies have had a few years of experience with one or more of the periodic six-month reassessments since initial registration.

Registration by a third-party organization, generally called a registrar, means that a company's quality management and quality assurance systems have been audited against the written standards. Registration is conferred only after a successful on-site audit by a team of auditors and recognizes that a company has in place a fully documented system that it consistently follows. Subsequently, chemical companies say that they have started to see tangible results, such as improved efficiency and cost savings, from being ISO 9000 registered.

ISO 9000 is not a product certification standard; registration in no way measures or recognizes the quality—good or bad—of a company's final product nor does it mean that two companies with ISO 9000 registrations are equivalent. To presume otherwise is probably the greatest misconception, and perhaps misuse, of ISO 9000 standards. However, ISO 9000 may play a role in product liability and other legal matters through the technical documentation it creates.

Separate registrations can apply to individual company sites, divisions, facilities, operations, or production processes, or a single registration may cover multiple functions, sites, or even an entire company. Not counting DuPont's more than 200 registrations, which tend to be along product lines, the 38 companies surveyed by C&EN accounted for registrations covering more than 780 sites or business operations. About half of the companies had operations registered to ISO 9002 alone and another third had sites registered to ISO 9001, which covers design, and 9002. Two engineering firms had ISO 9001 registrations alone.

Companies seek ISO 9000 registrations for a few major reasons. Of the 38 surveyed companies, 24 cite internal quality management and continuous improvement initiatives as a reason for implementing ISO 9000 standards. But competition and market pressures, initially in Europe and now more frequently in the U.S., were mentioned by 23 companies. The third most important motivating factor, mentioned by 17 companies, is customer concerns, requests, satisfaction, or recognition.

These results correspond well with a July 1993 survey conducted jointly by the accounting firm Deliotte & Touche, located in Atlanta, and Quality Systems Update, a CEEM publication. Among the 110 chemical companies included in the 620-company survey, customer expectations and demands were ranked as the leading reason for registration by 26% of the companies and quality benefits by 23%. Contrary to once widely held beliefs as to why companies seek registration, marketing and competitive concerns ranked much lower, especially in Europe.

Historically, the drive for registration began in Europe because companies were worried that if they weren't registered, they would have difficulty doing business there, says Paul Z. Larson, vice president of operations for DuPont specialty chemicals. "As the company proceeded, it found that there were a lot of internal benefits to ISO 9000 registration." By the time its efforts are completed, DuPont expects to have more than 330 worldwide registrations. Most of its current registrations are in North America and Europe, although the company also has registered sites in Asia and Latin America.

Registration takes time, money

The cost, effort, and time companies say is required to achieve ISO 9000 registration suggest that it is not a process to be undertaken lightly. Depending to what level a company's operations already are documented, the process toward registration may move ahead more or less quickly. Based on information from 31 of the 38 companies surveyed by C&EN, chemical companies estimate that the average time to obtain registration is about 20 months. The shortest time needed was six months; the longest times were upward of several years, but the latter often represent "man-years."

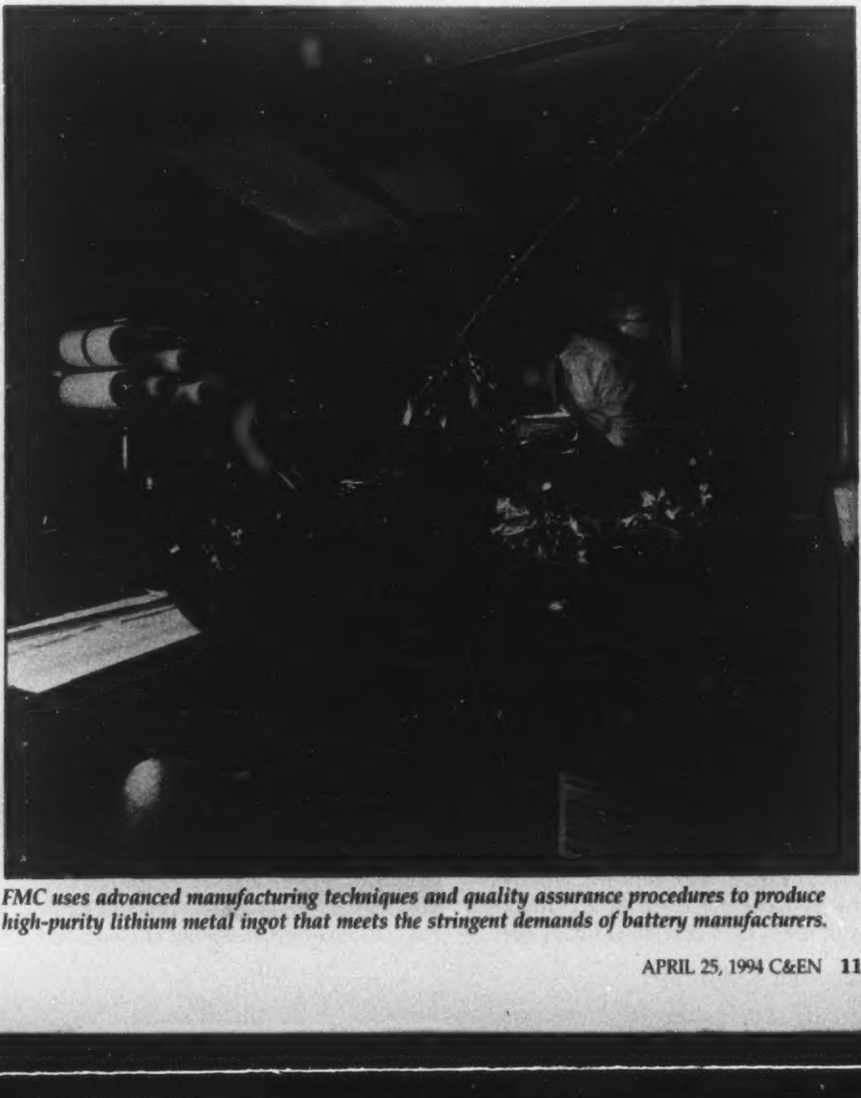
Estimates of the amounts of time and money invested vary depending on whether companies are working on multiple-site registrations, on the size of operations being prepared for registration, and on the accounting system for employee hours devoted to the project. The average cost, including both external costs for consultants and registration audits and internal preparation costs, was $316,000 per site based on information from 13 companies in C&EN's survey, as compared with $348,000 from Deliotte & Touche's survey.

Many companies do not count the internal costs of preparation, documentation, and training under a quality system. Instead, when existing employees are used in the process, the costs often are considered part of normal personnel expenses for employee activities related to necessary business functions. The costs for third-party audits ranged from about $10,000 to $30,000 per site according to 11 companies in C&EN's survey. Deliotte & Touche found the average external costs—including registrars and consultants, which are used by about half of the companies—to be $51,000.

Some chemical company quality or ISO 9000 managers estimate that costs can be recovered within six months to several years. Others in the industry believe that cost savings will be minimal. However, the vast majority—while expecting some positive return in the long term—say they cannot or have not quantified or documented any cost savings. Based on company figures from the Deliotte & Touche survey, average annual savings of $224,000 were calculated. In addition, costs and potential cost savings were found to scale directly with company size in terms of sales.

Long-term benefits

Whether the payback is concrete or intangible, those who believe there is one say that it is a direct and nearly immediate result of improved production processes, increased ef-



FMC uses advanced manufacturing techniques and quality assurance procedures to produce high-purity lithium metal ingot that meets the stringent demands of battery manufacturers.

ficiency and productivity, and decreased errors or nonconforming products as a result of corrective and preventive action. Companies in the Deliotte & Touche survey listed improved documentation (32%), greater quality awareness (26%), positive cultural changes (15%), and increased productivity and efficiency (9%) among the internal benefits.

"It helps simplify our processes, it drives us to look in detail at the many things we do every day and [to] examine the value of each step and eliminate those where we aren't adding value and add where we need some support," says Larson of DuPont. The results were a higher level of operating discipline, a better quality product, and a more economical way of supporting efforts at its plants. "[ISO 9000 also has made] it easier to move people around our plants as we've downsized," he says, "[by having] procedures that are very carefully developed, which helps in training efforts."

Many managers frequently express the axiom that ISO 9000 standards cause a company to "document what it does and do what it documents." The benefits are so significant, stresses Joan M. Desiderio, director of total quality at Lonza, Fair Lawn, N.J., that "if you are not going to use ISO 9000 for the internal benefits, you shouldn't even bother doing it." Since Lonza went through its preparation for complying with the standard at least two major internal benefits have been realized. One is having exactly documented company operations, outside actual manufacturing processes, for the first time. A second major benefit is that the process was a "tremendous educational experience and creator of teamwork," allowing employees to better understand the overall work process and their roles in it.

"I don't believe Lonza was unusual. I believe that most companies don't have a lot written down for their business processes, although they do for manufacturing," she says. "Yet there is so much talk about companies doing [corporate] reengineering, but they have no idea what is currently happening [in their company]. I don't understand how one can reengineer something when it isn't even known what that something is." Lonza has eight ISO 9002 registrations covering the company's headquarters, which has functions such as purchasing and customer service serving its plant sites, and seven plants.

Desiderio strongly believes that the key to the ISO 9000 registration process is having the employees who actually do the work create the documentation for what they really do. "Only if Lonza needed to fill a gap to comply with the standards did we want to change any [procedures]," she adds.

Not surprisingly, Lonza very definitely decided against using external consultants. Its employee involvement and documentation process have served the company well when it encounters a problem, explains Desiderio, because problems can be addressed very quickly and very consistently. Employees can see whether things were not done in accordance with the system and should have been or, if done according to the system, how the system should be changed to correct the problem.

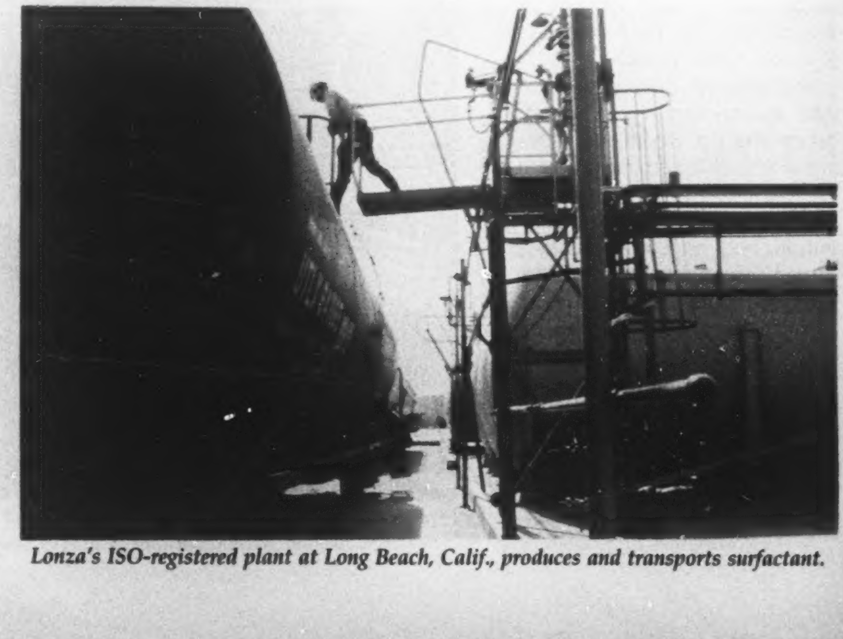
"The next step, which we are doing now, is to take the documentation and look at how we can improve it, how we can streamline it, how we can get rid of the non-value-added elements and find where we have built in some error that can be eliminated," she says. "And now we are starting with something concrete instead of just everyone's guesswork, so from that point of view we've built a lot of discipline and consistency."

External benefits also are expected from ISO 9000 registration. Of the chemical companies in the Deliotte & Touche survey, higher perceived quality was ranked first by 34%, increased customer satisfaction by 27%, and having a competitive edge by 22%. Since much of the impetus behind ISO 9000 registration is to meet customer quality assurance requirements, one often anticipated savings is a reduced number of audits by customers who recognize registration as a commitment to certain quality practices.

However, the survey found that only 9% of chemical companies cited reduced audits as an external benefit. Nonetheless, many companies do report that customer audits, even if they are not reduced in number, are shorter or that they focus on product performance or environmental, health, and safety issues not already addressed by the standards. And the converse also is expected to become increasingly more common as companies, having focused for some time on getting internal efforts in place, start to look outward and request ISO 9000 registration of suppliers or those who wish to be preferred suppliers.

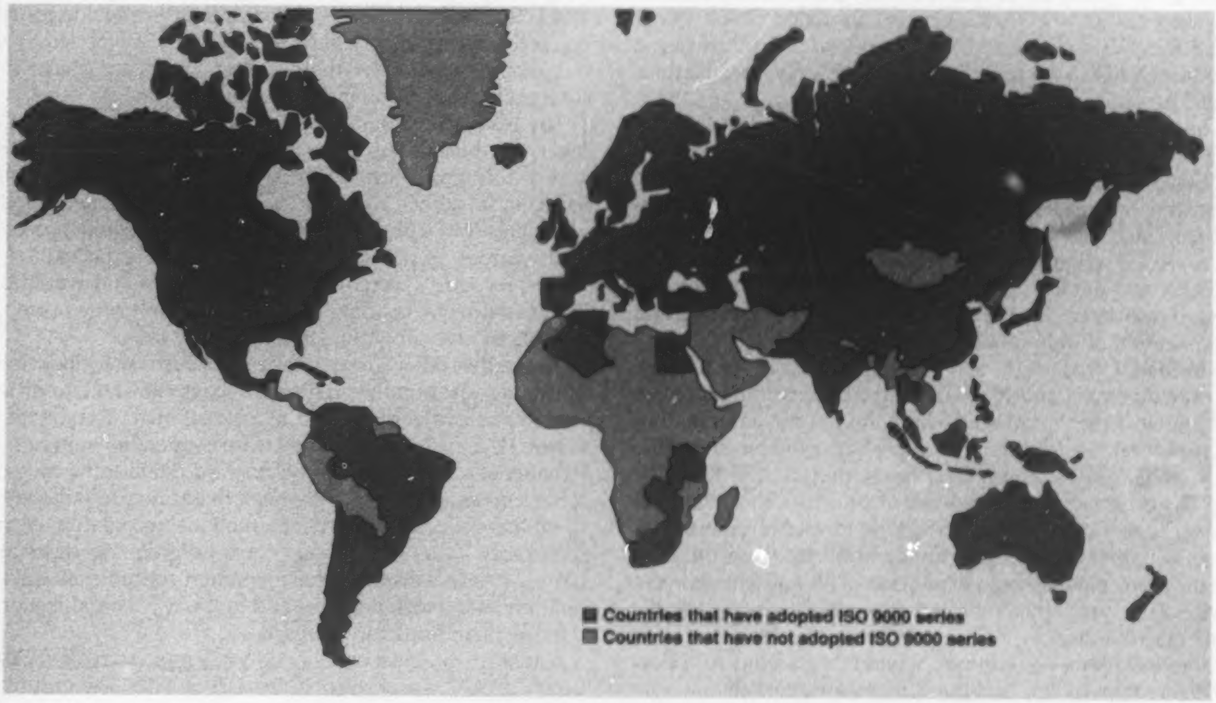
Registrar choice important

ISO 9000 registration carries weight only if it is recognized. Thus, the choice of an outside registrar often is dictated by customer acceptance. Although different registrars are used by different chemical companies, which individually also may use more than one registrar for different company sites, several registrars have amassed a great deal of



Lonza's ISO-registered plant at Long Beach, Calif., produces and transports surfactant.

Many countries worldwide have adopted ISO 9000 series as a national standard


▪ Countries that have adopted ISO 9000 series
▪ Countries that have not adopted ISO 9000 series

In January 1994, the 74 countries that had adopted ISO 9000 series were Algeria, Argentina, Armenia, Australia, Austria, Azerbaijan, Barbados, Belarus, Belgium, Brazil, Bulgaria, Canada, Chile, China, Colombia, Cuba, Cyprus, Czech Republic, Denmark (but not Greenland), Egypt, Finland, France, Germany, Greece, Hungary, Iceland, India, Indonesia, Ireland, Israel, Italy, Jamaica, Japan, Kazakhstan, Kyrgyzstan, Malaysia, Mexico, Moldova, Netherlands, New Guinea, New Zealand, Norway, Pakistan, Philippines, Poland, Portugal, Romania, Russia, Singapore, Slovakia, Slovenia, South Africa, South Korea, Spain, Sri Lanka, Sweden, Switzerland, Taiwan, Tajikistan, Tanzania, Thailand, Trinidad/Tobago, Tunisia, Turkey, Turkmenistan, U. K., Ukraine, Uruguay, Uzbekistan, U.S., Venezuela, Yugoslavia, Zambia, and Zimbabwe. The standards have also been adopted by the European Union.

Source: CEEM Information Services

experience in the chemical industry. According to CEEM, 10 registrars account for about 91% of U.S. chemical company certifications, and each lists chemical industry certifications as between 15 and 50% of their business.

Leading the group is Quality Systems Registrars, Herndon, Va., with just more than 100 registrations, followed closely at 96 by the joint registration activity of Underwriters Laboratories, Melville, N.Y., and British Standards Institution (BSI), located in the U.S. in Tysons Corner, Va. BSI, in addition to being part of the British organization involved in standards writing, serves as a registrar and accounts for nearly 80 registrations in the U.S. chemical industry.

Quality Management Institute, in Canada, and Det Norske Veritas Industry Americas, the Houston-based arm of the Norwegian DNV, each has about 50 registrations in the industry. Companies with just more than 30 chemical company registrations each are ABS Quality Evaluations, Houston; Bureau Veritas Quality International, Jamestown, N.Y.; Lloyd's Register Quality Assurance, Hoboken, N.J.; SGS International Certification Services (formerly SGS Yarsley), Hoboken; and Underwriters Laboratories.

In addition to knowledge about a particular industry sector, registrars generally are chosen by chemical companies on the basis of other factors such as their reputations, capabilities, experience, and location. Many choices are dictated by concerns about a registrar's own accreditation standing and the training and certification of a registrar's auditors. Companies also may look for registrars that have dual accreditation from, or a mutual recognition agreement between, the two countries in which its plant sites to be registered are located.

Having spoken with and screened many potential registrars, Lonza's Desiderio says the choice of registrar was dictated not only by accreditation, knowledge, costs, and location, but also by the registrar's philosophy. "What I liked about [the registrar chosen] was that they clearly understood that Lonza is in the business of manufacturing and selling chemicals," she says, "and that we are not in the business of designing quality systems.

"Many of the registrar companies I talked to gave me the impression that, in their view, Lonza's reason for being should be to have a great quality system and that the company only manufactures chemicals on the side. The registrar [chosen had] a certain business common sense, but with the integrity that Lonza still had a standard to meet."

What has not yet been formalized is an international accreditation system for the recognition of registrars or for the certifications of individual auditors. On a national level, many different institutions exist to recognize these organizations. In Europe, many accreditation groups are governmental or quasi-governmental bodies. Two more established ones are the Dutch Council for Certification (RvC) and the National Accreditation Council for Certification Bodies (NACCB) in the U.K. However, only RvC certifies registrars outside of its own country.

In the U.S., the Registrar Accreditation Board (RAB) was formed in 1989 as an American Society for Quality Control (ASQC) affiliate. RAB, which has accredited 15 third-party registrar organizations, has joined with the American National Standards Institute (ANSI) in the accreditation process. ANSI represents the U.S. as a member of ISO. RAB, ASQC, and the U.K.-based Institute for Quality Assurance (IQA) also have developed programs for the training and certification of individual auditors.

In March, RAB, IQA, and the Quality Society of Australasia in Australia and New Zealand signed a mutual recognition agreement. Although there are not as many auditor certification organizations as there are registrar accreditation bodies, says George Q. Lofgren, president of RAB, the need for harmonization is evident in certification too. The agreement states that, while working toward a uniform system of requirements for certifying auditors, these three organizations have enough experience with and enough confidence in each other's current programs to recognize the others' certifications.

Organizations accrediting registrar firms tend to follow criteria set up by ISO and the other major international standards organization, the International Electrotechnical Commission (IEC). A set of similar standards, under the European Norm (EN) 45000 series, also are used. EN standards are issued by the standards-making organizations for the European Union (EU)—the European Committee for Standardization (CEN) and the European Committee for Electrotechnical Standardization (CENELEC).

In response to the EU's preference for government-related recognition systems, the Department of Commerce, acting through the National Institute of Standards & Technology (NIST), has proposed the National Voluntary Conformity Assessment System Evaluation (NVCASE) program. This program will provide a basis, with other federal agency programs, for the U.S. government to assure other governments that U.S. assessment bodies are competent to provide results acceptable for regulatory purposes. ISO 9000 is expected to be one requirement under the evolving European system for conformity assessment and regulated products.

The NVCASE program will apply not only to ISO 9000 registrars, but also to organizations doing product testing and certification, such as ANSI. A proposed rule was published in July 1993, and NIST has since incorporated public comments into a final document now in the review process. In its current form, the NVCASE program is expected to be able to recognize accreditation organizations and would be involved directly in accrediting registrars only when acceptable alternative programs do not already exist.

Numerous other groups have been formed to look into the issues surrounding registrar recognition and to share information. In early 1993, the International Accreditation Forum (IAF) was created to increase cooperation among international accreditation bodies toward establishing mutual recognition agreements. "We need to harmonize our activities if there ever is to be true international recognition of the registrations that are issued," says Lofgren. He describes IAF as a "user's group" where common concerns as well as differences in work practices and in the ways organizations interpret standards can be discussed.

Similarly, the Independent Association of Accredited Registrars (IAAR) was formed in the U.S in 1993. The group of accredited registrars is attempting to promote consistency among registrars and ensure integrity of the registration process. In addition to trying to reach a nonbinding consensus on an interpretation of the ISO 9000 standards, IAAR is addressing how organizations that offer both consulting and registration services can avoid conflicts of interest.

"The main thing is to make sure that this whole process has merit," says Yehuda Dror, general manager of quality rating and certification at DNV. "Because if the registration process is not perceived as having value, then it's just another paper exercise." And, while admitting a certain level of self-interest, Dror adds, "From what we have seen and what industry tells us, compliance with the standard as manifested by a registration has real value."

Internationally, ISO and IEC have established the Quality System Assessment Recognition (QSAR) committee to make recommendations on a system for the worldwide recognition of registrars. Lofgren, a QSAR member, says the group has produced an initial draft document that has gone through a comment period by ISO and IEC members (the national standards organizations). QSAR met this month to consider these comments before its recommendations are forwarded to ISO and IEC for their September meetings.

QSAR initially came to the conclusion, says Lofgren, that international recognition at the registrar level would

Lonza's esters and surfactants production plant at Williamsport, Pa., has successfully competed the ISO certification process.

ISO 9000 standards cover quality management systems

The International Organization for Standardization (ISO), based in Geneva, issued the ISO 9000 series of voluntary standards for quality management systems in 1987. Updated versions of the standards will be issued in final form this year.

The five generic standards provide guidance in setting up quality management systems. These standards apply to the elements and practice—primarily through documentation—of such systems, but not to the specific form or means for implementation. Nor do the standards set any technical or performance requirements. Third-party certification against the standards indicates that a company has a documented quality management system in place and follows it consistently. The five standards are:

- ISO 9000. Entitled "Quality Management and Quality Assurance Standards: Guidelines for Selection and Use," it is a guidance standard, setting forth principal concepts and defining terms. It also introduces the other four standards and provides guidance on the selection and use of ISO 9001, 9002, and 9003 standards.
- ISO 9001. Provides a model for quality assurance in the design, development, production, installation, and servicing of products or services. The most comprehensive of all the standards, it includes all of the requirements found in ISO 9002 and ISO 9003.
- ISO 9002. Provides a model for quality assurance in production, installation, and servicing. In the revised standard, ISO 9002 includes servicing but, unlike ISO 9001, it does not include design elements.
- ISO 9003. The least comprehensive standard, it provides a model for quality assurance when only final inspection and testing are required.
- ISO 9004. In contrast to the other standards, this one offers guidelines for developing and applying internal quality management elements and activities. It also looks in more detail at elements contained in ISO 9001, 9002, and 9003.

Originally designed to be used in two-party purchaser-supplier contracts, the ISO 9000 series of standards is being applied broadly through third-party certification of a company's quality system operations. In practice, the most important standards are ISO 9001, 9002, and 9003, which require some, but not all, of the same 20 elements as listed in CEEM Information Services' ISO 9000 Handbook, 2nd Edition.

System element	ISO standard		
	9001	9002	9003
Management responsibility	●	●	●
Quality system	●	●	●
Contract review	●	●	●
Design control	●	●	●
Document and control data	●	●	●
Purchasing	●	●	●
Control of customer-supplied product	●	●	●
Product identification and traceability	●	●	●
Process control	●	●	●
Inspection and testing	●	●	●
Control of inspection, measuring, and test equipment	●	●	●
Inspection and test status	●	●	●
Control of nonconforming product	●	●	●
Corrective and preventive action	●	●	●
Handling, storage, packaging, preservation, and delivery	●	●	●
Control of quality records	●	●	●
Internal quality audits	●	●	●
Training	●	●	●
Servicing	●	●	●
Statistical techniques	●	●	●

● = Comprehensive requirement.
● = Less comprehensive requirement than in ISO 9001 and 9002.
● = Not present.

become unworkable because of the growing numbers of registrars. However, there has been strong support from some quarters for a system that includes peer recognition of registrars. QSAR's initial recommendations instead were aimed one level up—at the bodies which accredit registrars.

"What was envisioned is that there will be some system of peer evaluation and mutual recognition among the accreditation bodies," he says. "When that exists . . . all of the registrars that have been accredited by a recognized accreditation body will be able to issue a certificate that perhaps has a unique ISO-IEC mark on it. And that mark will be the mechanism through which eventual, universal recognition will be achieved." Whatever form the international system takes, many people anticipate that there will be an acceptance period, not only by countries, accreditation bodies, and registrars, but also by clients and customers, that will be critical to the process's ultimate success.

Barriers and criticisms

Many people hope that ISO 9000, as an international standard, will establish consistent international practices and terminology for quality management. But the international recognition issues for registrar accreditation and auditor certification will take time to be resolved. And implementation of the standards faces criticisms and barriers.

In the Deloitte & Touche survey, 24% of the chemical companies indicated that document development was a main barrier to registration. Another 16% said that developing procedures was a significant barrier. These two activities also were listed as the most time consuming.

Company managers with experience in ISO 9000 registration admit that these can be problems, especially if a company is not careful in how it creates its documentation. The standards are generic and offer no specific direction for certain industry sectors or operations within sectors. To address this problem, industry trade associations—for example, the Chemical Manufacturers Association (CMA), the Synthetic Organic Chemical Manufacturers Association, and the Society of the Plastics Industry—and organizations such as ASQC have formed industry focus groups to offer workshops, training, and guidance in intrepeting the standards and applying them to specific activities.

One frequently mentioned criticism of the ISO 9000 standards is that they are overly bureaucratic, requiring excessive documentation. "ISO only indicates where you should have documentation, not how much you have to write," explains Dror of DNV, and the key is determining how much is enough. A related criticism is that the system becomes too unwieldy for practical application and doesn't represent what companies really need to have in place. But as experience with ISO 9000 implementation has increased, company managers say, so too has the ability to avoid potential pitfalls.

"The overall directive Lonza put in place for documentation was that it had to be user friendly," says Desiderio. "It wasn't being written to be put on a shelf and it wasn't designed to satisfy auditors ... and the company made it clear to [the auditors] that it was written for Lonza's employees and to reflect how the company runs its business." Lonza's procedures, which can be referred to by any employee through a companywide computer system, are flow charts rather than "detailed verbiage," she adds, and list only critical activities that must take place and who has responsibility. When needed, more detailed work instructions are documented.

Many chemical company managers surveyed by C&EN say that ISO 9000 is only one element of their larger total quality management system. Creators of the ISO 9001 through 9003 standards themselves state: "The requirements in these external quality assurance standards are viewed as minimum good business practices for a supplier company in any industry/economic sector." ISO 9000 standards, by providing basic directives for documentation and training, are considered an important foundation for use with other, broader, management programs.

Companies that use ISO 9000 registration as a trophy or a blue ribbon are met with suspicion, if not derision, by quality managers. And customers unfamiliar with the details of ISO 9000 registration may be too naive to know better. While admitting that registration offers a feeling of achievement and the desire to brag because of the effort required, these same company quality managers stress that ISO 9000 registration means only that a company has succeeded in putting a basic system in place.

ISO 9000 registration "only implies consistency," says Desiderio. "My next question would be: What's your consistency level? Because a company that is certified to the standard can be consistently mediocre in its products and services." Quality managers, like Desiderio, say it is how a system is used that will determine whether a company becomes a "class quality organization." "It's what a company does using that system and the standards it sets that will then allow it to become consistently better," she adds.

However, a frequent criticism of ISO 9000 standards is that in creating documented procedures the standards are too "static" and do not allow for change or continuous improvement. But again, company quality managers who support ISO 9000 say documentation forces a company to look at its processes and then serves as a framework within which consistent changes and improvements can be made. And changes that are a necessary part of staying competitive can be addressed in the reassessment process and can be achieved without falling out of compliance.

Changes in standards

Revisions to ISO 9000 standards are expected to be published this year, possibly by the summer, as part of an ISO requirement that standards be reviewed every five years. Modifications of the standards are expected to respond to marketplace needs and reflect the practical experience and problems organizations have had in using the standards. Although updating the standards to reflect both marketplace and technology advances, the changes are not expected to alter the form, intent, or continuity of the series but rather to improve their utility. Draft copies of the revised standards have been made public.

"I believe the new standards are written much, much better," says Dror. "They are streamlined ... and there is much less vagueness." In general, the revisions will provide better alignment throughout the series, clearer definitions of terminology and concepts, and an increased emphasis on an organization's customers and stakeholders. The conformance standards—ISO 9001, 9002, and 9003, which were designed to be used in two-party contractual situations—will "officially" recognize third-party registrations for external quality assurance activities. And revised standards are expected to discuss the specific role of documentation in a broader range of areas.

Companies should not misinterpret these requirements necessarily to mean that they must generate more paper, says Dror. "Even though there was no requirement on documented procedures for purchasing in the old standards, I have yet to see any company that doesn't have [purchasing documented]," he states as an example. "I think that ISO took the reality [of what people were doing] and tried to align the system around it." The modified standards also will address one of the most frequently asked questions, he adds: that of whether documentation for a quality management system can be computerized.

Whether the changes have a major or a minor impact on a company's quality system and registration will depend on how an organization previously complied with the standards. "Organizations that looked at the standards and tried to do just the basic minimum to comply probably will have a bit more difficulty than those who did it more with an eye for what works for them," explains Dror. He points

Union Carbide's wire and cable semiconductives compounding facility at the Seadrift, Tex., petrochemical complex is ISO registered.

Board accredits U.S. ISO 9000 registrars

The Registrar Accreditation Board (RAB), based in Milwaukee, is a private-sector organization that accredits organizations to conduct quality system assessments. Established by the nonprofit professional group, the American Society for Quality Control, it has joined with the American National Standards Institute (ANSI) to assure the competence of third-party registrars. Of at least 45 registrars practicing in the U.S. and Canada, including North American arms of many overseas registrars, 11 have applied for accreditation under the ANSI-RAB program. Another 15, currently with RAB accreditation, are awaiting recertification under the joint ANSI-RAB program:

- ABS Quality Evaluations, Houston.
- American Society of Mechanical Engineers, New York City.
- A.G.A. Quality, Cleveland.
- AT&T's Quality Registrar, Union, N.J.
- Bellcore Quality Registration, Piscataway, N.J.
- Bureau Veritas Quality International, Jamestown, N.Y.
- DLS Quality Technology Associates, Camillus, N.Y.
- Intertek Services, Fairfax, Va.
- KPMG Quality Registrar, Montvale, N.J.
- Lloyd's Register Quality Assurance, Hoboken, N.J.
- National Quality Assurance, Boxborough, Mass.
- Quality Systems Registrars, Herndon, Va.
- Steel Related Industries, Wexford, Pa.
- TRA Certification, Elkhart, Ind.
- Tri-Tech Services, Pittsburgh.

out that the accreditation bodies have indicated to registrars that the organizations they audit will have to be in compliance with the revised standards one year from the date of publication.

Registrars are taking different approaches, says Dror, but in general are expected to offer a "grace period" before clients must comply with the revised standards. For example, DNV sent out an advisory note outlining how it plans to make the transition. He explains the procedure: If a company's periodic reassessment audit comes within three months of publication, the company will be assessed against the revised standards but any noncompliance issues will not affect registration. However, by the next six-month audit, or for those whose audit comes after three months, the new standards must be met.

Companies that have not yet had their initial registration audit with DNV, but will have it within three months of publication, can choose to follow either the old or new standards, although DNV recommends following the revised ones, says Dror. Regardless, DNV recommends that companies begin preparation by looking at the draft standards, because the substance is fixed even though editorial changes still may be made. Registrars already are willing to assess companies with respect to the modified standards but, because the modified version is still a draft, cannot yet register them, he adds.

The revisions to come out this year are the first part of a two-phase review strategy by TC 176, the ISO technical committee that developed the ISO 9000 standards. Whereas the original standards were designed with hardware manufacturing in mind, the phase II revisions are expected to further integrate concepts, technology, and terminology among four generic product categories—hardware, software, processed materials, and services. Revised standards also are anticipated to include broader quality management concepts such as continuous improvement, customer satisfaction, and procedures to be used by companies to track product quality performance.

TC 176 hopes the revised generic standards will meet marketplace needs and help avoid the proliferation of industry or other sector-specific standards either supplemental to or derived from the ISO 9000 series. Four strategic goals are set by TC 176 for the ISO 9000 standards—universal acceptance, current compatibility, forward compatibility, and forward flexibility. Phase II revisions are expected before the end of the decade.

Environmental standards

Before the major revisions to ISO 9000 standards are published, new standards for environmental management are expected from ISO. Despite many anticipated similarities to ISO 9000 standards, early expectations are that the environmental standards will, at least initially, be separate ISO 14000 series standards. To ensure continuity among all of the standards and avoid duplication or redefinition of terms or concepts, a coordination group has been formed between TC 176 and TC 207. But many people who follow, or are involved with, standards development expect the next ISO 9000 revisions to include, or at least reference, the environmental standards.

"There are a lot of aspects to the environment that are quite different from quality," says W. Ross Stevens, senior program manager for corporate issues at DuPont and a member of TC 207. "The fundamental difference is that quality is a contractual arrangement between a buyer and a seller, whereas the environment is a much more complex relationship in which a full range of stakeholders must be satisfied."

Growing worldwide environmental concerns have heightened the interest in companies' having EMS, in part to meet regulatory requirements and to report on performance. Many regional and national—voluntary and mandatory—activities are emerging. Because there are many similarities among various emerging standards, there is a desire to "level the playing field" through a single, comprehensive, and generally accepted scheme for environmental concepts and practices.

In the interest of harmonization and facilitating trade, ISO hopes to avoid simultaneous development of regional and international standards. Thus, it is working rapidly to develop international EMS standards, and, if successful by the mid-1995 deadline, have them accepted by CENELEC and CEN for use under the Eco-Management and Auditing Scheme (EMAS) in Europe. "Do it once, do it right, do it internationally" was the motto presented by James L. Dixon, secretary of TC 207 and program manager for the Canadian Standards Association at a joint ANSI, ASQC, and ISO conference last October.

TC 207 held its first meeting in June 1993 and the mo-

ISO 9000 plays important role for chemical producers and engineering firms

A C&EN survey of 36 companies that responded to questions on ranking found that ISO 9000 standards are an element that affects at least 10 different areas of company operations.

The most important impact of ISO 9000 standards is considered to be its enhancement of internal quality management or practices, followed closely by its importance in overseas operations and a company's ability to compete. The areas in which ISO 9000 is considered of less importance are relationships with suppliers and the related area of customer and supplier audits. ISO 9000 standards are deemed to have some positive economic impact, but this did not rank as high in importance as most of the other areas.

When broken out by company type, the overall trend in responses remains. However, diversified and specialty manufacturers rank the importance of ISO 9000 in overseas and domestic operations, as well as the ability to compete, higher than do the manufacturers of basic chemicals. Similarly, ISO 9000's importance in customer and supplier audits ranks lower with basic chemical producers. Diversified manufacturers see ISO 9000 of lesser importance in the areas of internal improvements. And engineering companies ranked all areas as very important or higher, except for relationships with suppliers and in customer or supplier audits.

	Average response by company type (No. of companies)				
Area of company operation	Total (36)	Specialty (13)	Basic (16)	Diversified (5)	Engineering (2)
Overseas (non-U.S.) operations	3.7	3.9	3.4	4.0	4.0
Domestic (U.S.) operations	3.3	3.5	3.1	3.4	4.0
Positive economic impact on business	3.1	3.1	3.0	3.2	4.0
Ability to compete	3.7	3.8	3.4	4.0	4.5
Enhancing internal quality management or practices	4.0	4.1	3.9	3.6	4.5
Improved quality of products or services	3.5	3.5	3.5	2.[illegible]	4.5
Simplifying or improving operating procedures or training	3.6	3.8	3.6	3.0	4.0
Relationships/interactions with customers	3.3	3.2	3.4	3.2	4.0
Relationship with suppliers	3.0	3.0	2.9	3.0	3.5
Reduced need for audits by customers and/or suppliers	3.2	3.5	2.9	3.6	3.0

Companies were asked to rank the importance of ISO 9000 in 10 different areas, the results of which are shown in the table above. A ranking of five signifies crucial, four very important, three important, two mildly important, and one not at all important.

mentum has been strong ever since. With 30 member countries and eight observers, TC 207 has divided itself into six subcommittees and one working group in the areas of EMS, environmental auditing, environmental labeling, environmental performance evaluation, life-cycle analysis, terms and definitions, and environmental aspects in product standards. The full committee will meet the week of May 9 in Australia.

Like ISO 9000, the new standards are expected to be guidance documents for setting up EMS rather than prescriptive standards. "The mission of TC 207 is standardization in the field of environmental management systems and the operative words are 'management systems,' " says John E. Master, staff executive with CMA and a member of TC 207. "The standardization addresses the best known ways of managing environmental objectives and does not deal with the setting of [those] objectives."

Although not an area for direct involvement, environmental performance is a concern of TC 207, explains Master, who also is executive adviser for environmental health and safety at Arco Chemical. "But the closest TC 207 has come to addressing that is to recognize the concepts of continuous improvement and of sustainable development, and you will find those phrases in many of the developing documents." To require organizations to meet prescribed performance levels could be harmful to relationships between developing and developed countries. "We cannot use international standards to support or create trade barriers," he says.

Industry involvement

Master and Stevens are two of several U.S. chemical company representatives participating in TC 207. Master is chairman of the U.S. Technical Advisory Group (TAG) to the Environmental Performance Evaluation (EPE) Subcommittee and Stevens serves as a convener of one of its working groups. "CMA concluded very early that it didn't want TC 207 and EMS [standards development] to go the same way [as ISO 9000 had]," says Master. Assuming that the development of ISO 9000 standards would be primarily a European activity, "CMA essentially ignored the process," he explains. "But of course [it] didn't take very long to find out that [CMA's assumption] was not true."

Initially believing it would just monitor TC 207 in preparation for the outcome, Master says, "CMA very quickly recognized that there was an opportunity to influence the development of standards and really participate in the process." An ad hoc CMA committee headed by Master monitors TC 207, reviews each subcommittee's activities and progress, looks into issues that are important from a chemical industry perspective, and assesses how solid and well accepted the U.S. position is in the international arena.

CMA's committee has helped establish a chemical industry position, says Master, "but even more important, it has helped solidify positions and helped to strengthen the ability of the U.S. to advocate its positions and really achieve some pretty good results." The chemical industry is just one of many U.S. industry groups represented on TC 207 through an ANSI TAG. "I don't want it to appear like the chemical industry is trying to grab all the glory," says Master, "but none of [the other industries] have the same kind of proactive organization and leadership that the chemical industry has."

Chemical industry representatives to TC 207 believe that chemical industry positions have been very consistent with those of the rest of U.S. industry. However, both Master and Stevens, as well as others, express concern that most of the participation has been from industry and not from other interest groups. "It means that, in the end, we may not have the degree of buy-in from other interests that we ought to have relative to the value of a voluntary standard," warns Master.

The Environmental Protection Agency and the Department of Commerce have been active, says Stevens, and work is being conducted with the National Wildlife Federation toward the inclusion of environmental interests. Liaison organizations to TC 207 also include the International Chamber of Commerce, the International Institute for Sustainable Development, the United Nations Environment Program, and the World Wide Fund for Nature. Another goal of TC 207 is to gain better representation worldwide, including that from developing or newly industrialized nations, as well as consumers and small- and medium-sized businesses.

Environmental management standards could affect international trade and environmental law, and act as tools to support voluntary private-sector initiatives such as Responsible Care, the Global Environmental Management Initiative, the CERES Principles, and the International Chamber of Commerce's Charter for Sustainable Development. In the view of one major U.S. petrochemical company, an effective international protocol would accomplish the following:

- Be simple, understandable by the public, and compatible with existing management systems.
- Focus on management systems, not on efforts to set performance or impose prescriptive operating guidelines.
- Be flexible and adaptable to a variety of operations and local operating, customer, and community needs.
- Enable local industry, community, and government interests to balance economic and environmental considerations that are based on sound science.
- Provide management the freedom to run the business at a level consistent with the company's accountability, including output requirements established by local government.

Environmental management

Despite the concerns, TC 207's subcommittees have moved ahead at a pace generally viewed as unusually fast for ISO. "At the rate that things are moving, I would expect there will be an ISO EMS standard [from the EMS Subcommittee] that will emerge by the end of 1995," says Joel B. Charm, director of occupational health and product safety at AlliedSignal and chairman of the U.S. TAG to the EMS Subcommittee. At a recent meeting in Toronto, significant progress was made in the development of working drafts of specification and general guidance documents.

The specification standards eventually may be used by an organization to comply with the EMAS or for third-party or self-certification of an organization's EMS. These standards, Charm explains, will contain core requirements that all parties agree are necessary for an EMS. "They tend to be issues that companies already should be addressing, or have in place, and have documented procedures that they are meeting requirements," he says.

For example, among the requirements are that an organization have a published environmental policy and overall environmental management principles, documented procedures, annual objectives and targets for performance, measurement systems in place, and a means for reporting on how the overall EMS is working. Charm points out that although there is agreement that companies should be reporting, there is not yet agreement on what would be needed in such a report.

Guidelines being developed, while looking at the specification standards, also will consider emerging issues. These guidelines are for issues that everyone generally agrees should be addressed, explains Charm, but for which there isn't yet an agreed upon process on how to address them. They include how an organization can go about setting up an EMS, how to get management involved, what kind of continuous improvement should exist, and what issues should be considered in external reporting.

"The specification [standards] represent compliance," Charm points out; "the guidelines are beyond compliance." At a future date—most likely when the EMS standards are revised—issues for which there is now little agreement will be considered. Despite facing regional, national, and legal questions in trying to reach a consensus on the environmental management standards, TC 207 has made much progress in a short time.

"The U.S. has been one of the major negotiators at the table," says Charm. "I guess it might be characterized as the U.S. on one hand versus the Europeans, led by the U.K., on the other. We have tended to gather a lot of support, particularly among the Asian countries and some of the European countries." Having worked very hard to prioritize its positions and build consensus within the U.S. delegation,

DNV auditor performs an ISO audit with a client.

British Environmental Standard: A model for ISO?

The British Standard Institution's (BSI) standard BS 7750 for setting up environmental management systems (EMS) has recently been republished on the strength of a very detailed pilot program. Hundreds of companies participated in "using" an early version of the standard last year, says Reg Blake, manager of business development at the U.S arm of BSI in Tysons Corner, Va. Although many countries and companies are taking a look at the standard, says Blake, they are not yet being officially certified.

The standard, first published in March 1992, is meant to be compatible with ISO 9000 standards and contains similar features, but it can also be used as a separate standard. BS 7750 has long been assumed to be a model for many of the concepts in, while not the exact format of, evolving ISO environmental management standards. BS 7750 serves to guide a company in the formation, management, and execution of an environmental policy and system. According to CEEM Information Services, some of the required elements of an EMS, under BS 7750, include the following:

- The organization must develop a full environmental plan that specifically details the objectives and targets of the EMS and the means that will be used to achieve them.
- The organization must be in compliance with all applicable environmental legislation.
- The organization's EMS must be able to respond quickly to the ever-changing world of environmental legislation.
- The organization must compile a register of all environmental regulations and legislation that affect its business and must use it to ensure that the previous requirement is met.
- A full review of the environmental impact of the organization's operations, including site assessment, must be performed.
- The organization must assign environmental management responsibilities to employees, defining exactly who will manage the EMS.
- Personal environmental targets for individual employees have to be assigned.
- The organization must train its employees to understand the potential problems that may arise if they stray from the defined EMS.
- Proof of continuous improvement in environmental performance must be provided.
- Specific procedures must have environmental targets that must either be met over time or be reviewed and changed.
- Records regarding the achievement of objectives and targets, including the disposal of waste materials, must be kept.
- Internal audits must be conducted.
- The organization must periodically review its EMS and its compliance with the standard.

the group also built liaisons with individual members of other delegations, says Charm, "so we have support for our position at the meeting as a whole.

"All of this has helped keep our consensus together ... which is very important because ultimately what will be important for the work of TC 207 is the overall acceptability of the standard when it is finally published. The U.S. fundamentally is in support of having an environmental management standard evolve through this system. ... Otherwise we would be faced with having different standards in different regions of the world and for multinational [corporations] which operate in a number of different countries. It's much easier to have one standard."

There have been a few controversial issues, he says, one of the most controversial being that of continuous improvement and how it is applied. The debate centers on whether continuous improvement should apply to emission levels—such that a company has an obligation to continually reduce emissions—or to the overall performance of a system. The latter position, supported by the U.S., seems to be carrying through in how the standard is emerging, explains Charm.

Another issue is related to the amount of detail that should be contained in public disclosures. "Our view is that we in the U.S. probably are required to disclose far more in the environmental area than any other country in the world," says Charm, who acknowledges that Germany now has extensive disclosure requirements. "When the rest of the world comes up to that standard, we would then entertain additional disclosure requirements."

The question of whether an environmental effects registry should exist is also fairly controversial, he adds. The standard appears to be emerging with the focus away from the creation of a public registry that would list the potential effects of products and their manufacture. "What we have been able to do is [say] that there should be a requirement for the determination of the environmental aspects of activities," says Charm. "And then that information should be fed into the objectives that an organization sets for itself internally, including the question of continuous improvement."

There has been much speculation that the ISO EMS standards will look like British Standard 7750, a precedent that has been tested in the U.K. this past year. "There is a certain similarity in that the concepts are the same, but some of the detail is significantly different," says Charm. To strike a compromise between European interests for more prescriptive standards and the U.S. position that the EMS standard should be as performance based as possible, much of the kind of detail which appears in BS 7750 will be taken out and may be put in an interpretative annex or guidance document.

Other subcommittees

The Environmental Audit and Environmental Performance Evaluation (EPE) Subcommittees also are making progress, says Master, who hesitates to give specifics before the subcommittees have had a chance to present their work at the TC 207 meeting in May. The Subcommittee on Environmental Aspects of Product Standards may soon present a working document, but he says the group has "backed off" on one for approval to allow more time to deal with various issues and develop a consensus.

Results are probably "several years down the road" from environmental labeling and life-cycle assessment. "These subcommittees are moving along, but they have a lot of development work to do," he says. "There is just not the database and technology in place at the present time to really support [labeling and life-cycle assessment], and standardization is going to take a lot more work."

The EPE Subcommittee has developed a framework document to present at the Australia meeting, having tried to reach compromises on many issues between what Master calls "very strong differences of opinion [on the part of] various participating countries."

Master says much of the debate has focused on the definitions of environmental performance and EPE. "One thing that the EPE group has recognized is that environmental management can't take place in a vacuum," he explains. "It can't take top priority in every situation to the exclusion of the other requirements of an organization's total management system, which has to include the interests of the government, customers, suppliers, communities, employees, stockholders, and all the other stakeholders."

Because there are so many different views of whether an organization is performing well, adds Stevens, "guidance to assist companies in describing and evaluating their performance is one area generally recognized by stakeholders to be of great value." The current thought of the EPE Subcommittee, he says, is that there are three major areas for evaluation and consideration: An organization ought to look at how well its management systems are operating, it ought to look at how well its operational systems are working, and it should also look at the linkages between those operational systems, processes, facilities, and the environment.

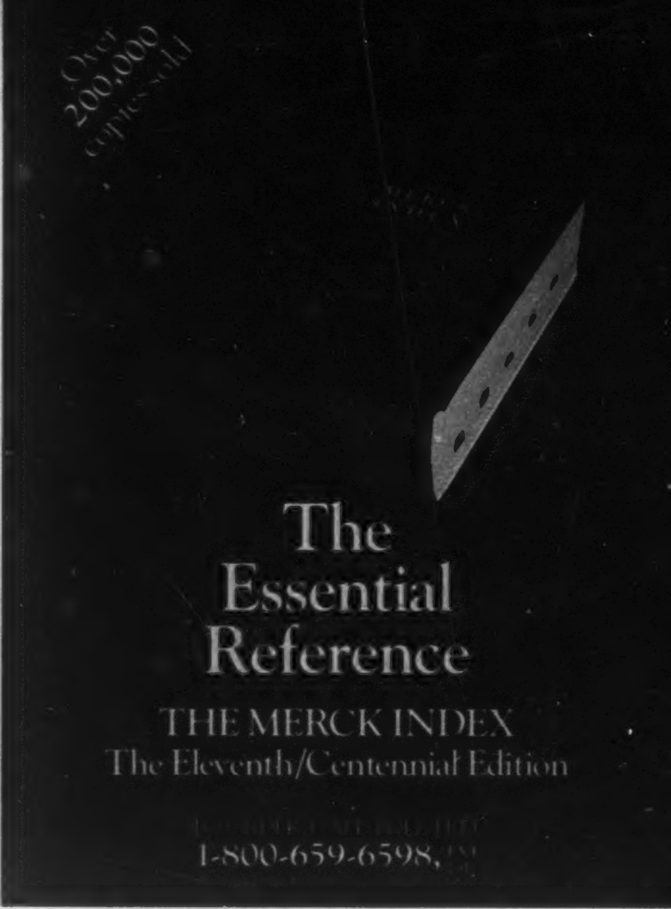
"In the end, companies can't look at 85 indicators," he says. "They are going to be looking at a handful of really critical indicators of performance and managing around those. And our process would be to give them guidelines to do that effectively and make their own choices, which will be good choices." The standards are being written to be flexible, says Stevens and others, to be used by companies for either internal or external company assessment or both.

For example, the standards would allow organizations to identify independently the specific legal or regulatory requirements they must meet and show that they are addressed within a management program. "For that reason, targets or rules absolutely will not be identified as a part of the standards-setting process," he explains. "It will simply say that the certifying company has to know the rules, it has to measure its progress, and it should be able to show evidence that it is doing that."

Implications of certification

The question remains as to what form that evidence will take and whether it will be considered credible by those outside an organization. A third-party certification process for EMS is still being developed and there are many concerns about exactly what it will require. Most of these concerns center on how much proprietary information will be made available to auditors and to what extent information about a company's environmental management is made public.

People involved in standards development suggest that third-party registration, in analogy to ISO 9000, will certify that an organization has set up an EMS. "It will be a certification that the system is in place and that it is functioning, but not the details of how it's functioning," says Charm.



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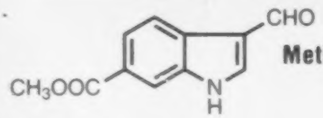

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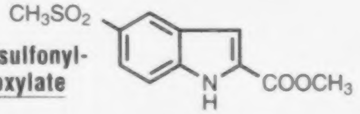

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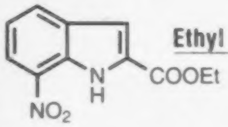

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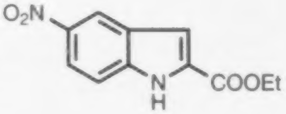

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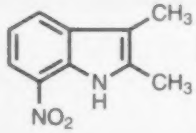

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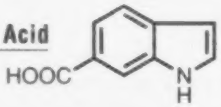

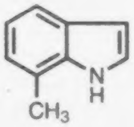

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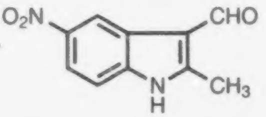

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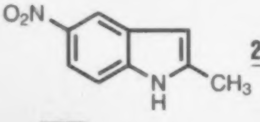

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"There will be [other] requirements in the standard for environmental audits, for performance reviews, and for an overall management review with followup improvements to be identified. So if an organization is being certified that its system is in place, then by definition it is also being certified that it has the internal systems."

There is a distinction between third-party registration for EMS and the standards work being developed by the Environmental Audit Subcommittee. This subcommittee is working to develop standards for use by organizations to internally audit their EMS to see if proper procedures are in place, that the system is adequate, and that it is being implemented. Emerging in Europe is another audit scheme, the Eco-Audit, which requires an organization to have an EMS and to make public an annual, independently verified self-assessment.

A clear distinction should be made between audit and third-party verification, says Master, because audit is a "red-flag word" in the chemical industry. Most companies look at auditing as an internal tool for the value of internal management. "The chemical industry still has a concern about release of audit findings to the public in any form," he says, "and that is a position I doubt will ever change because to [do otherwise] destroys the value of an internal audit system if your results have to be communicated. . . . It is very critical to preserve the confidentiality and the proprietary nature of that knowledge."

Public disclosure raises concerns about regulatory actions, litigation, and liability issues. "There are valid concerns within the chemical industry about 'opening the door and leaving it unlocked,'" says Stevens. "But I think there is a recognition that third parties have a real role—they do add credibility and they bring objectivity to one's own assessment—and you already see activities beginning to take place in the setting of Responsible Care to try to determine the most constructive way for third parties to be involved.

"Public disclosure will be part of this process. It's impossible to deal with the question of environmental management and environmental performance without dealing with the question of communication or reporting. You'd have to be blind not to see the very many initiatives that are around us today trying to provide guidance in this area. And one of the fundamental reasons for getting involved in ISO is to bring some uniformity and harmony to the state of the art."

Many of the companies surveyed by C&EN supported the idea of EMS standards, especially if third-party registration would reduce the number of audits by governments or regulatory agencies. Although the EMS standards are being designed to harmonize the concepts and the approach used worldwide in EMS, they will retain a degree of flexibility to allow organizations to respond to local, regional, and national laws and regulations. So, while they will level the playing field internationally in many respects, the nonprescriptive ISO standards are not anticipated to preempt local sovereignty.

However, people close to the emerging standards suggest that through environmental management standards, organizations may eventually move toward comparable levels of performance. "I believe that by improving the management of your environmental system or any other system, you are going to improve the performance," says Master. "What's going to happen over a period of time is that, by bringing in concepts of continuous improvement and sustainable development, everybody will be driven through their management systems to better performance."

Industry reaction to EMS

The reaction to emerging environmental standards from companies surveyed by C&EN was very mixed. Although more than three quarters gave some support to the idea, the support did not extend to all of the potential elements. Others gave qualified support, depending on exactly how the EMS standards might be implemented. Reasons for support included a desire for consistent international interpretations, easier compliance with or acceptance by national regulatory bodies, increased efficiency in operating overseas, and improved environmental management worldwide.

A spokesman for one major chemical producer indicated support for environmental management standards as long as such standards are "appropriate, timely, meaningful, and nonbureaucratic." Like many other chemical company representatives, he adds that companies already audit their environmental, health, and safety management programs worldwide and "generally require higher than local standards." At the same time, support for new standards often stems from a desire to level the playing field among different local standards.

Many indicated that no environmental standards or third-party registrations were needed because of existing voluntary initiatives such as Responsible Care and regulatory reporting programs such as EPA's Toxics Release Inventory. At the same time, others welcomed third-party audits because of their involvement in these programs. Of the companies which supported environmental management standards, about half were in favor of third-party registration, generally believing it to be inevitable and, they hope, a means for companies to gain public confidence.

A spokeswoman for a global chemical company says that as a member of CMA, "the company adheres to the principles of Responsible Care which has embedded in it management principles for safety, health, and the environment. Since the company's ultimate responsibility is to society at large, it is verification to society that it is concerned about." Like many others in the industry who anticipate that third-party verification in the environmental and other arenas is an eventuality, she still questions whether this "will satisfy all interested parties."

However, a spokesman for Exxon Chemical says the company does not consider "turnkey third-party evaluations ... heavily supported by some, mostly consulting firms, who have a vested interest in the outcome" to be a sound approach. "There is no single set of environmental measures that is appropriate for differing types of businesses and facilities," says the spokesman. "The complexity is an order of magnitude more difficult than financial performance. ... Furthermore, assessment requires a combination of skills and knowledge that presently reside only within industry."

Another area in which there is little agreement is whether new standards should be separate from the ISO 9000 series. Whereas several companies believe that there would be value in having "ISO 9000-like" principles applied to environmental matters, others leveled the same, and other, criticisms as those raised for ISO 9000 standards. But by and large, in light of numerous voluntary and mandatory initi-

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DuPont's plant in Wurtland, Ky., has received ISO certification.

atives that exist for all facets of company operations, the reaction of chemical companies was that EMS standards would be workable only if they could be combined with existing programs and auditing procedures.

CMA has focused on integrating such programs, says Master, and also is trying to respond to public demands and develop a verification process for company self-assessments under Responsible Care. One possible route is to couple the goals set through Responsible Care with ISO 9000 and EMS standards, using one third-party registration to cover all three. An important industry issue is reducing the number of audits, he adds, because plant managers are spending more time responding to audit requests—for both voluntary and regulatory programs—than concentrating on managing facilities.

Separate audits may not be needed, say registrars such as Dror at DNV and Reg Blake, manager of business development at BSI, because of the anticipated similarities in structure and documentation between EMS and ISO 9000 standards. What may be required instead is some additional assessment activity and effort on the part of the auditing team to evaluate a management system that has been expanded to cover more aspects of a company's operations. But they emphasize that auditors will need training, as they have for different industry sectors, and possibly certification to deal with environmental standards.

However, there are reservations among registrars about environmental auditing. Currently, Blake says he knows of no registrars yet accredited for EMS because the accreditation bodies are considering the risks of any liabilities after certifying a company's environmental system. "It could be that only certain accreditation bodies and registrars may offer this service. It's a commercial decision that they'll make based on a risk assessment about whether to get involved in a particular market."

Based on his experience with the BS 7750 standard, Blake says that prior compliance with ISO 9000 is a "good vehicle for integrating a BS 7750 approach into the organization." In a drive to be more efficient and simplify work procedures, many companies have already started integrating programs covering different aspects of operations, with some even looking at BS 7750. And CMA has been developing guidelines showing the interrelationships between initiatives such as Responsible Care, ISO 9000, and the Occupational Safety & Health Administration's Process Safety Management.

Among the most common approaches mentioned by companies is to consolidate environmental, health, and safety requirements into quality management systems. And, although the broader total quality management systems encompass these efforts, the procedures and practices of ISO 9000 frequently are used to form the foundation for documentation, auditing, or training. Still, companies must be careful to track the elements of each separate program to demonstrate and ensure compliance.

But the question of integration, at least between the ISO 9000 and EMS standards, may be moot within a few years. "In one of the later revisions of ISO 9000, I anticipate there will be either a direct incorporation or a direct reference to what will now be the ISO 14000 series," says Charm, "such that if you want to be ISO 9000 registered in the future, I believe that you will also have to have the environmental management system in place." Thus, if the chemical industry continues its commitment to the ISO 9000 standards, it may very soon find itself without a choice. □

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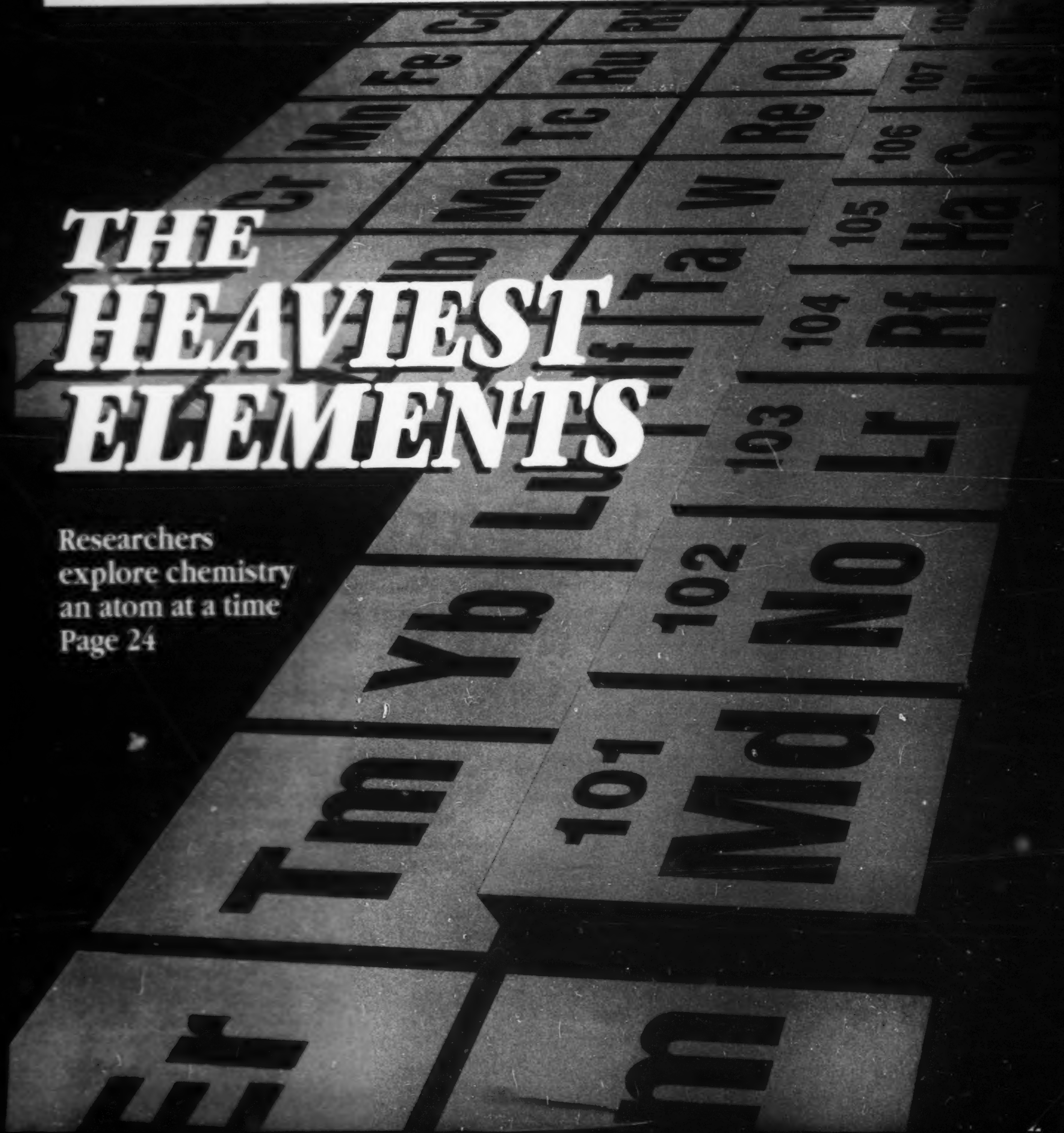
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THE HEAVIEST ELEMENTS

Researchers explore chemistry an atom at a time Page 24

CHEMICAL & ENGINEERING NEWS

C&EN

MAY 2, 1994

NEWS OF THE WEEK

- ACS-sponsored permanent exhibit, "Science in American Life," opens at the Smithsonian in Washington, D.C., accompanied by press briefing, symposia, other events. Page 4
- First-quarter earnings of U.S. chemical firms released so far continued increases begun in last year's second quarter. Page 5
- The first oriented growth of molecular sieve (zeolite) crystals on surfaces has been achieved by Purdue University researchers, possibly opening up new catalytic uses. Page 6
- Administration unveils legislation to reform U.S. pesticide laws, particularly as they affect food safety; provisions draw criticism from both industry and public interest groups. Page 6
- DuPont agrees to pay $214 million to settle 220 lawsuits by growers claiming damage to their crops from Benlate fungicide; company says move is not an admission of liability but a way to cut court costs. Page 7
- A number of chemists and chemical engineers are among new members and foreign associates elected to the National Academy of Sciences. Page 7

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BUSINESS

Worldwide production of man-made fibers grew 2% last year despite declines in Europe and Japan—up enough to cause fiber makers to be optimistic for 1994. **Page 10**

U.K. chemical capital spending is leveling off following two years of steep decline, but will head down again after next year, according to the Chemical Industries Association. **Page 12**

Business Insights: U.S. chemical firms will step up their investment overseas about 6.5% to $6.61 billion this year, the highest since 1990, although this may change by year's end. **Page 13**

GOVERNMENT

Trade agreement signed last month protects government support of industry R&D and alleviates most concerns, particularly the U.S.'s possible loss of control of its own laws. **Page 15**

Government's success in transferring technology to industry was praised in hearings aimed at heading off proposed legislation over pricing of federally supported projects. **Page 16**

SCIENCE/TECHNOLOGY

Preparation of divalent species of carbon, silicon, and germanium is prompting chemists to ask whether studying these stabilized versions will help them better understand the transient, highly reactive molecules they are modeled after. **Page 20**

Catalytic reduction of nitrogen oxides with ethene and propene at temperatures at which automobile catalytic converters operate produces significant amounts of hydrogen cyanide, Swiss researchers report. **Page 22**

EDUCATION

National Research Council's draft education standards draw mixed reactions at a science education forum in Atlanta. **Page 23**

ACS NEWS

Official reports of various ACS committees from the spring national meeting in San Diego are highlighted. **Page 37**

SPECIAL REPORT

With just a few atoms—that may exist for only seconds—scientists investigate the chemistry of the elements heavier than fermium. Page 24

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LETTERS

Nobel Laureates and gender

I am in complete agreement with Victor J. Linnenbom's statement (C&EN, March 28, page 3), "Scientific achievement based on individual accomplishment, rather than group entitlement, must continue to be the sole criterion for selection [of Nobel Prizes]." Like Linnenbom, I decry "political correctness" and the assumption that failure of a particular ethnic group or sex to be represented in awards, jobs, or entitlements by its exact percentage in the general population is prima facie evidence of racism or sexism that must be combated by mechanical application of quotas or affirmative action. In my review of "Nobel Laureates in Chemistry 1901–1992" (C&EN, Feb. 14, page 32) my statement, "Nearly three decades have elapsed since the last selection of a female chemistry laureate, a situation that cries for rectification," was intended as a criticism not of the Nobel selection process but of the woeful underrepresentation in chemistry of women, our most undervalued and underutilized "minority" research resource.

Such unusually low representation of women in science, their struggle merely to be allowed to study science and then, as full-fledged researchers, to obtain suitable positions; to juggle their roles as scientists, wives, mothers, and homemakers; to overcome nepotism rules; to have publications accepted and grant proposals funded; to be admitted to professional societies; and to be adequately rewarded with recognition, honors, and awards is not only my opinion, but a well-documented fact and a problem that is finally receiving attention of late. In C&EN alone, it has been the subject of articles [for example, "Programs Seek To Draw More Women into Engineering and Science" (June 14, 1993, page 43) and book reviews, "A Hand Up: Women Mentoring Women in Science" (Dec. 13, 1993, page 49); "Lifting the Veil: The Feminine Face of Science (Dec. 20, 1993, page 40); and, most pertinent to Linnenbom's concern, "Nobel Prize Women in Science: Their Lives, Struggles and Momentous Discoveries" (April 11, page 41)]. Recently, *Science* devoted much of its March 11 issue to the feature "Women in Science 1994: Comparisons Across Cultures."

Also, 1993 Nobel Laureate in Chemistry Michael Smith of the University of British Columbia donated $175,000 of his approximately $525,000 award to Canadian Women in Science & Technology, a group that encourages women to take up careers in science. He hoped that his action would lead others to do likewise, and he stated, "Male scientists have a responsibility to be supportive and be advocates" of women who want to pursue science (*Calgary Herald*, March 29, page B2).

Manfred E. Wolff's statement that "numerous chemists have been honored by the award of the Nobel Prize in Physiology or Medicine (C&EN, April 11, page 2) is indeed correct. However, it is not I who ignored this fact but the editor of "Nobel Laureates in Chemistry 1901–1992," a perfectly understandable exclusion considering the book's title.

George B. Kauffman
Department of Chemistry
California State University, Fresno

I was saddened as I read Victor J. Linnenbom's letter, about the book review by George E. Kauffman. It illustrated again for me why the struggle to turn the diversity of American society into a strength that allows all members of this society to contribute their full potential of skills and knowledge has been such a battle.

Linnenbom jumps to the conclusion that, when Kauffman said rectification, he meant that the way awarding Nobel Prizes

Continued on page 53

Correction

- Jan. 31, page 20: The World Bank is not now funding DDT plants and has never funded such facilities. The bank will continue to fund public health projects in which DDT is used to control vector-borne diseases, specifically malaria.

Letters to the Editor

C&EN encourages readers to contribute to this letters section. However, please keep letters reasonably short—400 words or fewer. Because we receive a heavy volume of letters, persons writing letters are limited, as a general rule, to one letter within any given six-month period.

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Global Output Of Man-Made Fibers Rose Moderately In 1993

■ ***Led by synthetics, production grew 2% despite drop in Europe and Japan; fiber makers optimistic for this year***

Patricia L. Layman, C&EN London

World production of man-made fibers—which includes synthetics and cellulosics—grew in 1993, rising 2% from 1992 levels, to a record level of 20.3 million metric tons, according to the annual production survey by Dutch fibers company Akzo Nobel. The rate of growth has slowed slightly—it was up 3.1% in 1992, for example—but still was up sufficiently to give fiber makers an optimistic picture on a global basis.

The increase in production was solely due to continued strength in synthetic fibers, including polyester, nylon, and acrylics, according to Friedrich W. Fröhlich, board director of Akzo Nobel responsible for its fiber activities. Production of cellulosics—acetate and rayon—remained at the previous year's level, so their share of total world man-made fiber production continued its gentle slide, to 13%.

According to data presented by Akzo Nobel, the three largest man-made fiber-producing countries—Taiwan, South Korea, and China—now account for just under 30% of total production. And other Southeast Asian countries are increasing production as well.

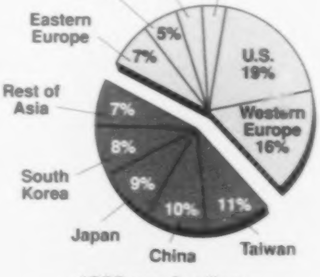
On the other hand, 1993 production in Western Europe declined 5% to 3.3 million metric tons, 16% of the world market. Production of man-made fibers in the U.S. benefited from the economic recovery there, increasing 2% to 3.9 million metric tons and retaining a 19% share of world output. In Japan, which is suffering serious economic difficulties, weak demand led to a drop in man-made fiber production of 5% to 1.8 million metric tons in 1993.

Akzo Nobel is understandably concerned about its own backyard—Western Europe—where the continuing recession resulted in lower demand for textiles and clothing last year. In addition, the region's textile industry suffered from a high level of imports, even though exports increased slightly.

The European fiber industry's major outlets—the textiles and transportation industries—each were hit particularly hard by a combination of recession and structural change. For example, over the course of the year, production volume was down 8% and prices tumbled 14%. "It is very difficult to meet a target productivity average" under those conditions, Fröhlich observes.

Akzo's results in 1993 in the fibers sector were a good illustration of the difficulties the European fibers industry had last year. Sales for the year were $1.70 billion, down 14% from 1992, although that was in part because of divestments during the year. And from an operating profit of $66 million in 1992, the company slid into an operating loss of $11 million last year. The company shipped 279,000 metric tons of fibers last year, a reduction from the 304,000 shipped in 1992, and capacity utilization was only 81%, versus 85% in 1992.

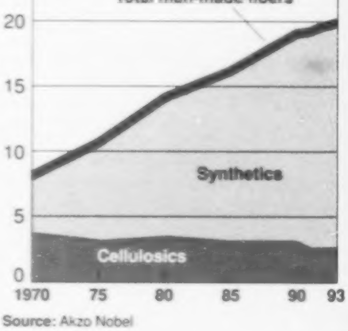
Almost half of man-made fibers are produced in Asia



1993 production = 20.3 million metric tons

Source: Akzo Nobel

World output of man-made fibers up 2% in 1993



Source: Akzo Nobel

As Fröhlich notes, however, "On the whole, we can say that we did relatively well in a year that was simply disastrous for the man-made fiber industry." And he leaves no doubt about goals for 1994: "This year, we have to write clearly black figures."

Toward that goal, fourth-quarter orders have begun to brighten some prospects. "We see an increase in demand for polyester filament and staple," he says. "We are not completely sure if it is pipeline filling or a major business improvement, but we are optimistic for the rest of 1994. That means an increase in our prices of 5 to 10%—we do not accept new orders without price increases now, in light of the strong demand."

Akzo Nobel is investing heavily in Kunstseidenwerk Elsterberg, the site in Saxony it acquired from the German government privatization agency, the Treuhandanstalt, in September 1993. Says Fröhlich, "This will be the world's most advanced production plant for textile viscose filament yarns" serving that specialized market.

And although demand for nylon yarns for industrial uses did not reach the level of the previous year in Western Europe, the company is also scrambling to supply nylon yarns for uncoated fabrics for air bags, a market in which it is perhaps the leading producer worldwide. "It is growing so exponentially we have difficulty keeping up," Fröhlich says. By 1998–99, the market will be saturated, he predicts, but until then, things are hopping.

Uncoated fabrics make up nearly all of the European market for air bags and "we [at Akzo] have a dominant proportion—but it will not stay that way." In the U.S., coated nylon fabrics, about 50% more expensive to produce, are still the majority of that sector, but the technology is changing rapidly. And in Japan, fiber producers have licensed Akzo Nobel's technology for air bag production.

The company was running losses in its polyester business last year, as it also has been in its Twaron aramid fibers, subject of a lengthy patent battle with DuPont. That was settled several years ago, but last July, the company was hit by an antidumping suit covering para-aramid fibers coming into the U.S., following a complaint by the sole U.S. producer of para-aramids, DuPont.

In December, the U.S. Department of Commerce fixed a preliminary antidumping duty of 47% on Akzo's fibers. Commerce's final verification on margins is expected this week, followed in June by a ruling from the International Trade Commission on the case. As Akzo Nobel officials point out, the formula for determining a "fair price" for sale in the U.S. included, among other factors, the assumption of a 10% profit—of dubious value when the company has been registering a loss on aramids all along.

"We believe in a fair ruling," says one Akzo Nobel official. "And if so, the conclusion has to be that there is no injury to the U.S. industry, to which we have been exporting only since 1992." He and his colleagues, however, are not sanguine about the outcome: They point out that 90 to 95% of all rulings in cases made by U.S. companies against European competitors go against the Europeans.

The aramid sector, nevertheless, continues to be attractive for Akzo Nobel. Last year, the company decided to boost annual capacity to a total of about 10,500 metric tons, an investment that cost about $80 million. The expansion will be completed by mid-1995, the company says.

It is also continuing development of a new cellulosic filament fiber known tentatively as Newcell, with the commissioning of a pilot plant for the specialty fiber at its German plant in Obernburg, near Frankfurt. Because the fiber is a filament, it will not compete head-on with the Tencel premium viscose staple fibers being produced by Courtaulds, Fröhlich says.

In addition to the ongoing business activities of its fibers division, however, Akzo Nobel executives say their company, and the other fiber producers in Western Europe, must continue to work on modernization to lower production costs, and on restructuring to trim excess capacity and the number of producers.

Partners might help with investments in Europe; they also may ease producers' paths into the growing markets in Southeast Asia. That, for example, is a target area for Akzo Nobel's fibers division, which is of equal importance to the U.S. "All our seven business units [within the fibers division] are exploring opportunities for investments in China, Taiwan, and so on. Maybe we will have some developments there in the next couple of years," Fröhlich says.

Not all the Southeast Asian countries are having a grand time of it, however. According to a new study of the Korean synthetic fibers industry from the Seoul offices of New York City-based securities firm S. G. Warburg, 1993 was a bad year for the synthetic fiber industry, as the South Korean industry "experienced one of its poorest performances in 1993 due to oversupply, decreases in prices, and severe competition."

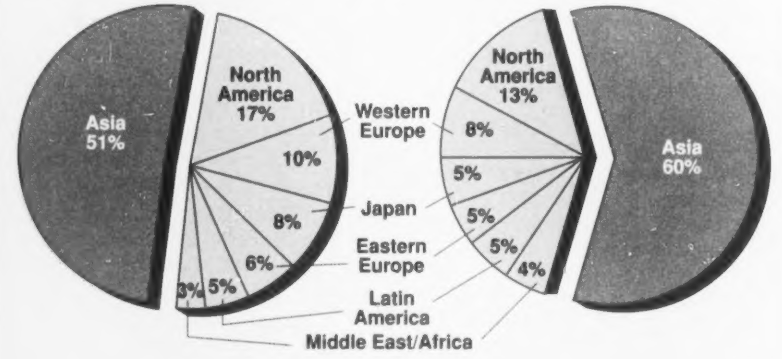
Polyester fiber capacity in South Korea, for example, increased 50% over the past three years, with polyester filament capacity booming 73% and staple fiber growing 23%. Polyester filament prices dropped 20% in 1993, although staple fiber prices remained stable.

Nylon was similarly beleaguered. Nylon filament capacity remained unchanged during the past three years, while staple expanded 24% during the same period. And a new entrant into the market sparked a price war that drove nylon filament prices down more than 25% over the course of last year.

As Warburg analyst Chae Kwang Lee points out in the report, using data from consultants Tecnon (U.K.) Ltd., four Asian companies—not including those from Japan—rank among the world's 10 largest polyester fiber producers: Nan Ya, Taiwan; Yizheng, China; Hualon, Taiwan/Malaysia; and Far East Textiles, Taiwan. "The rapid growth of polyester production in the Asian region is forecast to continue for the next 10 years," he says.

By 2001, Asia will account for 60% of the global market for polyester fiber. As the Warburg report points out, in 1979, the region accounted for only 18% of the total. ☐

Asia will solidify hold on polyester fiber use by 2001



1991 consumption = 9.17 million metric tons

Projected 2001 consumption = 15.1 million metric tons

Source: Tecnon (U.K.) Ltd.

U.K. chemical capital spending to end decline

Following two years of decline of about 10% per year, capital investment in the British chemical industry is leveling off, according to the recently released annual survey of the U.K.'s Chemical Industries Association (CIA).

After falling to about $2.87 billion from a peak of $3.29 billion in 1991, current-price investment this year will hold its own, according to the stated intentions of the companies—roughly two thirds of the group's membership—that took part in the association's survey. However, when adjusted for inflation, the amount intended for capital spending will decline slightly less than 1% from the levels of 1993.

According to Keith Wey, senior economist with CIA, companies have responded to the difficult economic conditions besetting the U.K. over the past several years by reducing their investment plans. Total chemical industry spending levels planned by companies for this year and next, he points out, are 13% below those forecast in the 1993 annual survey.

However, some features have remained the same. For example, investment in R&D facilities continues to account for more than one fifth of total capital investment. And for the second year in a row, more than 70% of new capital spending is designated for specialties and pharmaceuticals. Two years ago, as the industry was wrapping up several major projects, petrochemicals and plastics accounted for nearly 36% of the spending.

"Green" spending—for environmental protection, energy conservation, and health and safety—is expected to hold steady as well at about 27% of the capital spending of CIA members. That was down slightly from the proportion in 1993, Wey acknowledges, but he argues that the trend line is clear: From about 10% of total capital investment in 1990, spending on environmental protection likely will reach 20% by 1996.

On the positive side, Wey notes, this year's survey "continues to highlight the thrust of the industry toward pharmaceuticals and high-value-added products, and toward strong investment in R&D and increasing investment in environmental protection, which as we indicated last year, bring both costs and opportunities."

The fact that output of chemicals in the U.K. increased 2.7% in 1993 helps explain the leveling off of capital spending intentions for the next three years. "Total investment intentions for 1994 to 1996 add up to about $8.70 billion; in real terms, 10.5% down on capital spending achieved in 1991 to 1993. In view of the usual weakness in the third-year's figure, however, it could be argued that this represents a very modest reduction, particularly when set against some of the cutbacks expected elsewhere in Europe and Japan," he says.

In aggregate, European Union chemical industry new capital spending is forecast to fall about 1.5% this year, following a 15% decline in 1993. The declines last year were paced by Belgium (down 28.5%) and the Netherlands, (down 27%), as both saw completion of major petrochemical projects, and by Germany, down 15%. No growth in capital spending is expected in France or Italy this year, a further drop of 2% is expected in Germany, and only Belgium shows an increase—2.5%.

By comparison, U.S. chemical industry capital spending in 1993 was up 4.5%, points out CIA, although this is expected to drop back slightly, to 3.5% this year. Japan, which measured a 1% fall in chemical industry capital investment in 1993 from 1992, is bracing for a 22.5% decline this year.

CIA officials also found reason for optimism in that intended spending on new products is going up. Innovation, they contend, will be crucial for long-term survival of the industry.

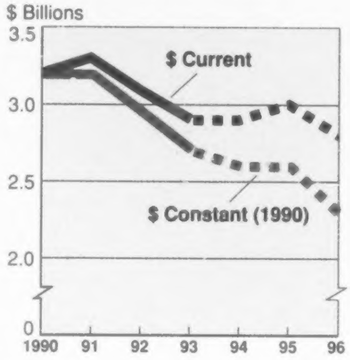
Robin Paul, deputy chairman and managing director of Albright & Wilson, and keynote speaker at the conference at which the spending survey was released, agreed on that point, but first tackled the obvious question of capacity expansion. "It is nearly always more profitable to increase the throughput on an existing plant rather than invest in new capacity," he says. "It requires a major breakthrough in technology to justify the complete replacement of existing capacity, and incremental output from an existing plant almost always costs less than building a new plant from scratch."

He offers a tip for getting the most out of existing facilities. "Our technique has been to appoint small commando teams of boffins [scientists] to observe every minute operation on the plant, round the clock, until they have a complete understanding of all the limiting factors in the plant's output. The team brings a blend of skills from plant operation, engineering design, and chemical research, and [the technique] is a first-class training opportunity for our younger employees."

In the long run, Paul notes, if a company is successful, the business will grow and it will have to invest. Companies deciding to invest in new assets, however, must seek genuine innovation—they can never earn an adequate return on new money by simply copying the last plant to be built or buying off-the-shelf technology available to competitors around the globe.

Patricia Layman

Spending won't rise when adjusted for inflation



Sources: U.K. government, Chemical Industries Association

Association members will hold R&D at fifth of their spending

$ Million	1994	1993
Product extension	$1,063.1	$1,005.5
Existing products	632.1	689.5
New products	431.0	316.0
Replacement/modification to existing facilities	488.4	488.4
Increased efficiency	344.8	258.6
R&D	632.1	632.1
Other	344.8	488.4
TOTAL	$2,873.2	$2,873.0

Source: Chemical Industries Association

U.S. chemical capital spending abroad expected to pick up

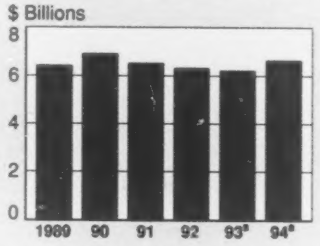
U.S. chemical companies, betting on a recovery in other major world economies, are planning to increase their spending on new plants and equipment overseas. According to the Commerce Department's annual survey of foreign capital-spending plans of majority-owned affiliates of U.S. companies, chemical and allied products producers plan to raise investment abroad about 6.5% to $6.61 billion in 1994. If this pans out, it will be the highest level of foreign spending since 1990, when capital spending abroad hit $6.90 billion.

However, it would not be surprising for the increase to change one way or the other, perhaps dramatically, by the time the year is through. For instance, according to the Commerce Department, in a June 1993 survey, producers thought that they would be spending more than $7 billion on chemical plants outside the U.S. in 1993. However, the survey taken at the end of the year shows that spending was more on the level of $6.15 billion.

Spending patterns have not changed much in terms of the areas into which the investment is going. Europe in 1994 will still receive the bulk of capital spending—62%, essentially the same as it did in 1993. Expenditures in Canada, however, will slip to 8.4% from 9.3% last year, and those in the Asia and Pacific grouping, which is usually called the Far East, will decline to 13.7% from 14.5%. Spending in Latin America and other countries in the Western Hemisphere will rise to 15.1% from 13.5%, and Africa and the Middle East will continue to receive about 1%.

Nevertheless, all the regions, except Canada, will show growth this year, according to the survey. Capital spending in Africa and the Middle East will rise 47% from a small base to $66 million. Spending in Latin America will grow about 20% to $998 million, followed by a 7% increase in Europe to $4.09 billion, and a 1% increase in Asia and the Pacific region to $905 million. Capital spending in Canada will decline about 3% to $554 million.

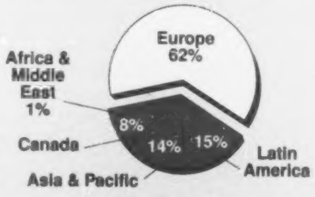
Overseas spending to rise to $6.61 billion



a Planned. Source: Department of Commerce

The numbers published by the Commerce Department throw cold water on the idea that the North American Free Trade Agreement (NAFTA), at least for the chemical industry, will cause a flight of investment from the U.S. to Canada or, especially, Mexico. Not only will investment decline in Canada if the current plans are carried out, but investment in Mexico will increase just 5%—less than the rate of increase worldwide. Most of the increase in Latin American investment in 1994 will come, not in Mexico, but in Brazil, up 40% to $392 million, where the Commerce Department says large increases are planned by industrial chemical producers.

Europe will get 62% of capital funds this year



1994 chemical capital spending = $6.61 billiona

a Planned. Source: Department of Commerce

The increase in chemical capital spending by U.S. companies in Mexico is significantly lower than the almost 27% increase planned for all manufacturing industries, which are forecast to spend nearly $2.24 billion on plants and equipment this year.

The modest increase in planned chemical capital spending in Mexico in 1994 is not surprising. Industry sources have argued all along that NAFTA would have only a moderate effect on capital plans of chemical companies. This is simply because the advantage of Mexican production in terms of cheaper labor is counter to the needs of the basic chemical industry, which is not labor intensive but rather heavily capital intensive.

And in a report on major foreign investment projects in Mexico this year, not even Mexico's Ministry of Trade & Industry (Secofi) would credit NAFTA for the rise in foreign investment in that country. The report listed 33 major foreign investment projects planned for the country by U.S. and other foreign companies. Worth more than $6.12 billion, these projects range from basic industries, such as automotive and chemicals, to retailing. Aliza Chelminsky, executive vice president of the Mexican Investment Board, a unit of the ministry, says, "A tide of direct foreign investment continues to flow into Mexico, as this announcement from Secofi demonstrates. The reasons behind the large influx scheduled for this year are basically the same as those that have impelled the huge amounts of foreign investment in Mexico in the past. Specifically, the country has achieved an extremely attractive environment in which to do business and to compete globally."

Chelminsky also points out that when President Carlos Salinas de Gortari took office in 1987, he was committed to doubling the value of direct foreign investment in Mexico from $24 billion, where it stood at that time, to $48 billion at the end of his term in office. However, she notes, today direct foreign investment is $72 billion, far exceeding the original goal.

William Storck

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CHEMICAL & ENGINEERING NEWS

C&EN

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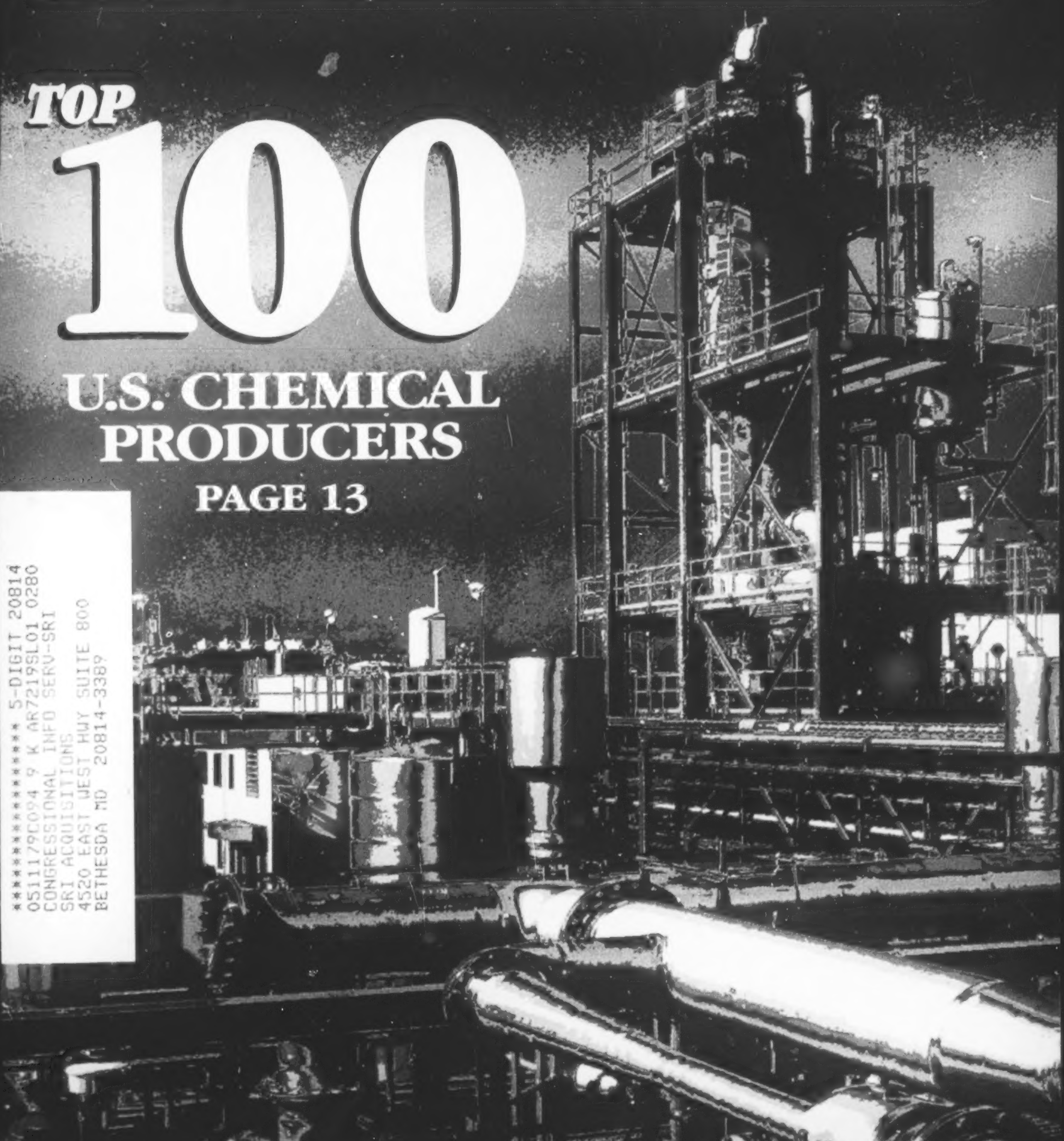

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C&EN

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- Researchers detect fullerenes in a tiny impact crater on the surface of a spacecraft—the first direct observation of fullerenes in space. Page 5
- A series of science programs for children will air on public TV beginning this fall, as the result of an agreement signed by Walt Disney's Buena Vista Television and the Public Broadcasting Service. Page 5
- North Korea continues to reject demands for international inspection of spent nuclear fuel at its research reactor, raising fears of plutonium diversion to build nuclear weapons. Page 6
- ACS staff relocates to temporary offices in first step of $8.3 million total renovation of Washington, D.C., headquarters building, expected to take about a year. Page 7
- Clinton Administration announces five-year, $1.2 billion government-industry cost-shared program to boost U.S. production of flat-panel displays. Page 7

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LETTERS

Grignard reagents

I was interested to learn of the continuing work on the mechanism of formation of Grignard reagents, as reported by Stephen Stinson (C&EN, March 28, page 31).

Walter J. Bowyer's use of leuco crystal violet as an in-situ indicator for Grignard reagent is a valuable contribution to experimental methodology for studying this important heterogeneous reaction.

I wish to correct an error in Stinson's report. It is true that George M. Whitesides' group reached the same conclusion concerning the overall sequence and timing of the corrosion of magnesium during the course of its reaction with alkyl halides 15 years ago. It is important to note, however, that the bulk of the group's work was carried out while Whitesides was at Massachusetts Institute of Technology, not Harvard.

To my knowledge, I was the second-to-last student of Whitesides' to work on the Grignard problem (trapping of free alkyl radical intermediates by reaction with tetramethylpiperidine-N-oxyl [*J. Am. Chem. Soc.*, **111,** 5405 (1989)]; rate of reaction of cyclopentyl bromide with a rotating disk of magnesium [*J. Am. Chem. Soc.*, **103,** 5475 (1981)]). Alan Izumi (who also worked on the Grignard reaction) and I were involved in moving to Harvard from MIT in August 1982 and did work in the Mallinckrodt Laboratories there; however, we both received Ph.D.s from MIT. As far as I know, Whitesides has not actively worked on mechanistic organomagnesium chemistry for several years.

The previous experiments of Whitesides cited in Stinson's report were part of Craig L. Hill's doctoral research at MIT [*J. Org. Chem.*, **45,** 1020 (1980)]. Hill is currently on the faculty at Emory University. Among their scanning electron microscopy results: The type of corrosion pits formed is influenced by the history of the metallic surface (only surfaces that had been carefully polished to remove surface defects yielded hexagonal pits); corrosion pits in single-crystal magnesium also have variable morphology depending on whether an alkyl bromide (known to undergo reaction at a mass-transport-limited rate) or an alkyl chloride (known to react much more slowly) is used in the reaction (specifically—smooth, hemispherical pits are observed after reaction with alkyl bromide, while regular, hexagonal pits are seen upon reaction with alkyl chloride). Clearly, the nature of the halide influences the selectivity of Mg^{2+} removal from the metallic lattice; however, the relative importance of kinetic versus thermodynamic factors in the latter stages of the reaction between alkyl halides and magnesium is not yet well understood.

I have another comment regarding the implications of Bowyer's experiments. Although ferric chloride may be used to increase reactivity of the magnesium surface, it may not be an ideal additive. Iron and other transition metals are known to catalyze side reactions (generally resulting in alkane and olefin by-products [*J. Am. Chem. Soc.*, **111,** 5405 (1989)]), thereby potentially decreasing the yield of organomagnesium product.

Karen Root Caldwell
Norwich, N.Y.

Unethical terminations

It is incongruous at a time when mass terminations are becoming epidemic in the chemical industry that the ACS unit probing such cases is being discontinued (C&EN, April 11, page 45). As your article indicated, the dichotomy between what the employer and the employee consider to be voluntary separation is widening, with reconciliation of differing views making it almost impossible to ascertain the true situation during an investigation of the circumstances of termination.

Unfortunately, companies are becoming more knowledgeable in avoiding age discrimination suits. Recently, one company that had been rapidly expanding its research staff during the past several years suddenly resorted to a mass termination where the dismissal of long-term employees was balanced by that of recent employees to present a picture devoid of old-age discrimination. With this scenario, the recent employees not only were subjected to arbitrary dismissal, but after establishing themselves in the community by buying houses were terminated with less than two weeks of pay per year of service—a negligible amount considering that most of the individuals had been with the company less than five years.

When both recent employees and older employees—the former looking for a career and the latter with long records of meritorious service—are simultaneously dismissed, the question arises as to the effectiveness of laws designed to protect workers against old-age discrimination. Maneuvering by corporations intent on removing older employees and yet avoiding costly lawsuits has brought a bonanza to law firms representing these companies. The law and ethics diverge at this point.

Nelson Marans
Silver Spring, Md.

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Top 100 Chemical Producers Post Little Sales Growth

■ ***Combined sales of leading firms in 1993 were better than in previous few years, but barely up from 1992***

William J. Storck,
C&EN Northeast News Bureau

Last year may have been a better year than the previous few for the chemical industry, but it is not evident from the sales performance of the Top 100 U.S. chemical producers. Hampered by lackluster demand and weak prices in 1993, the leading chemical producers hardly eked out an increase in sales of their chemical products. Any improvement in earnings came from cost cutting and better operating efficiencies rather than from increases in business.

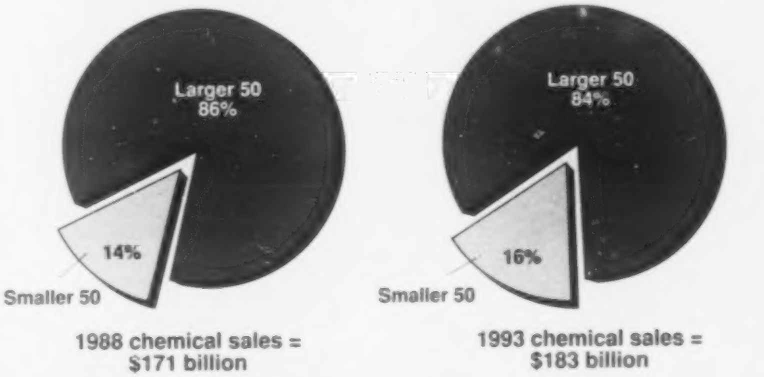
As a result, chemical sales for the Top 100 chemical producers last year totaled $183.4 billion. In 1992, the same companies had chemical sales of $183.0 billion. The sales increase might have been even smaller, had it not been for a pickup in consumer spending for big-ticket items such as automobiles and a rebound in housing sales in the second half of last year.

Although sales of the Top 100 companies increased little in 1993 over 1992, the $183.4 billion registered in 1993 was up from $181.0 billion for the slightly different list of companies that were included in the 1992 Top 100. And while 36 of the companies on the 1992 listing had sales declines, that number increased to 39 in 1993.

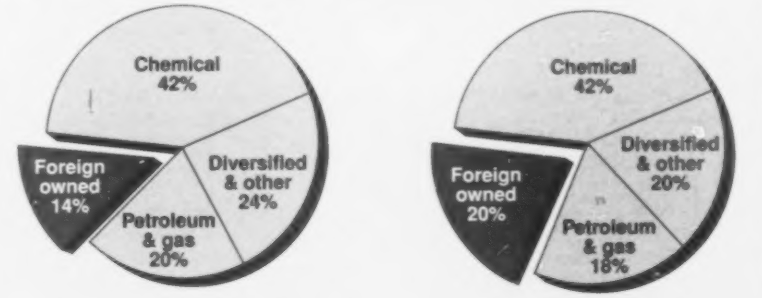
Companies on the 1993 list that were not included in 1992's are Huntsman Chemical, which, as a private company, had not provided data last year; Rexene, a Houston-based resins producer, which had been in a bankruptcy reorganization in 1992 and could not provide meaningful data for the 1992 ranking; Wellman, the fibers and plastics recycler and producer; Geon, the polyvinyl chloride producer spun off from BF Goodrich; Hanson, which owns SCM Chemicals and now Quantum; and Cytec, the chemicals spin-off from American Cyanamid. The largest company new to the listing for 1993 is ICI Americas, the U.S. arm of the U.K.'s ICI. The spin-off of ICI's agricultural chemicals and pharmaceuticals businesses into Zeneca has made ICI Americas pure enough in terms of chemical sales that it can now be ranked among the Top 100 U.S. producers.

There are still major chemical producers in the U.S. that are not included because either they do not break out chemical sales or they are privately held and do not report sales at all. Among the former group are such major companies as Procter & Gamble and 3M. And among the latter are J. M. Huber and PQ Corp.

In five years, the difference between sales by larger and smaller producers has changed little . . .



. . . but foreign-owned firms took a larger share from diversified and oil companies



Note: Based on chemical sales figures for Top 100 producers in 1993 and for those listed in C&EN, May 1, 1989, page 11.

Largest companies are most frequently hit by declining sales

Rank 1993	Rank 1992		Chemical sales 1993 ($ millions)	Change from 1992	Chemical sales as % of total sales	Industry classification	Chemical operating profits[a] ($ millions)	Change from 1992	Chemical operating profits as % of total profits	Operating profit margin[b]	Identifiable chemical assets ($ millions)	Chemical assets as % of total assets	Operating return on chemical assets[c]
1	1	**DuPont**	$15,603	0.4%	42.1%	Diversified	$750	-45.9%	51.7%	4.8%	$13,957	45.1%	5.4%
2	2	**Dow Chemical**	12,524	-3.1	69.3	Basic chemicals	773	30.6	53.7	6.2	12,530	49.1	6.2
3	3	**Exxon**	10,024	-5.7	9.2	Petroleum	638	-3.3	7.6	6.4	8,478	10.1	7.5
4	4	**Hoechst Celanese**	6,347	-2.3	92.0	Basic chemicals	561	26.9	155.8	8.8	na	na	na
5	5	**Monsanto**	5,651	5.0	71.5	Basic chemicals	731	17.5	90.2	12.9	5,312	61.5	13.8
6	7	**General Electric**[d]	5,042	3.9	8.3	Diversified	834	12.7	12.7	16.5	8,181	3.3	10.2
7	6	**Union Carbide**	4,640	-4.8	100.0	Basic chemicals	354	12.0	100.0	7.8	4,419	100.0	8.0
8	8	**Occidental Petroleum**	4,065	-3.8	47.6	Petroleum	184	100.0	84.8	4.5	5,780	33.8	3.2
9	9	**BASF**	4,037	-0.3	77.6	Basic chemicals	na	na	na	na	na	na	na
10	10	**Eastman Chemical**	3,903	2.4	100.0	Basic chemicals	476	-5.7	100.0	12.2	4,341	100.0	11.0
11	14	**Shell Oil**	3,875	18.2	18.6	Petroleum	328	89.6	23.0	8.5	4,312	16.1	7.6
12	12	**Amoco**	3,773	2.2	13.2	Petroleum	321	def	10.5	8.5	3,938	13.8	8.5
13	—	**ICI Americas**	3,565	20.0	100.0	Basic chemicals	188	45.7	100.0	5.3	na	na	na
14	11	**Mobil**	3,533	-4.6	5.5	Petroleum	25	-82.4	0.5	0.7	3,451	8.5	0.7
15	16	**Rohm and Haas**	3,269	6.7	100.0	Basic chemicals	267	-21.9	100.0	8.2	3,200	100.0	8.3
16	15	**Arco Chemical**	3,192	3.0	100.0	Basic chemicals	na	na	na	na	na	na	na
17	19	**Miles**	3,053	4.7	47.3	Diversified	na	na	na	na	na	na	na
18	18	**Air Products**[e]	2,906	3.6	87.3	Basic chemicals	417	-16.6	113.0	14.3	3,646	87.5	11.4
19	13	**W. R. Grace**	2,895	-16.7	65.7	Specialty chemicals	392	-9.9	103.2	13.5	2,115	39.5	18.5
20	21	**AlliedSignal**	2,791	7.3	23.6	Diversified	309	26.1	32.4	11.1	2,502	23.1	12.4
21	17	**Chevron**	2,708	-5.7	7.5	Petroleum	225	94.0	8.2	8.3	2,457	7.1	9.2
22	23	**Ashland Oil**[e]	2,586	3.9	25.4	Petroleum	108	12.5	36.4	4.2	958	17.3	11.3
23	22	**Ciba-Geigy**	2,519	-0.2	55.2	Specialty chemicals	na	na	na	na	na	na	na
24	20	**Praxair**	2,438	-6.4	100.0	Basic chemicals	341	23.6	100.0	14.0	3,255	100.0	10.5
25	26	**Phillips Petroleum**	2,308	3.7	18.8	Petroleum	97	148.7	9.1	4.2	2,011	18.5	4.8
26	27	**Akzo**	2,241	11.7	100.0	Basic chemicals	196	28.9	100.0	8.8	na	na	na
27	25	**Rhône-Poulenc**	2,200	-4.3	100.0	Specialty chemicals	na	na	na	na	na	na	na
28	29	**Dow Corning**	2,044	4.5	100.0	Specialty chemicals	236	11.9	100.0	11.5	3,265	100.0	7.2
29	35	**Ethyl**	1,938	14.5	100.0	Basic chemicals	168	-22.9	100.0	8.6	2,009	100.0	8.3
30	—	**Huntsman Chemical**	1,850	15.6	100.0	Basic chemicals	na	na	na	na	na	na	na
31	28	**Hercules**	1,843	-12.7	66.5	Basic chemicals	252	1.2	81.8	13.7	1,375	61.0	18.3
32	31	**FMC**	1,837	1.0	48.9	Machinery	197	-7.5	52.5	10.7	1,522	54.1	13.0
33	30	**National Starch**	1,808	-1.0	100.0	Specialty chemicals	288	3.3	100.0	15.9	1,672	100.0	17.2
34	36	**Great Lakes Chemical**	1,792	19.7	100.0	Specialty chemicals	415	15.0	100.0	23.2	1,901	100.0	21.8
35	34	**Elf Atochem**	1,700	0	100.0	Basic chemicals	na	na	na	na	na	na	na
36	38	**Lubrizol**	1,526	6.4	100.0	Specialty chemicals	190	2.6	100.0	12.5	1,056	89.2	18.0
37	24	**American Cyanamid**[d]	1,411	8.5	33.0	Specialty chemicals	na	na	na	na	na	na	na
38	40	**Nalco Chemical**	1,389	1.1	100.0	Specialty chemicals	263	1.0	100.0	18.9	1,212	100.0	21.7
39	39	**Lyondell Petrochemical**	1,326	-5.9	34.4	Petroleum products	57	-58.7	61.3	4.3	688	55.9	8.3
40	42	**Morton International**[f]	1,274	3.2	55.2	Specialty chemicals	135	-18.1	42.9	10.6	1,273	56.8	10.6
41	58	**Witco**	1,233	47.3	57.5	Specialty chemicals	108	45.7	94.5	8.8	1,037	56.4	10.4
42	45	**Solvay America**	1,200	4.4	100.0	Basic chemicals	na	na	na	na	na	na	na
43	44	**Cabot**[e]	1,192	0.9	73.8	Basic chemicals	149	-3.8	89.9	12.5	1,117	75.0	13.3
44	46	**International Flavors**	1,189	5.5	100.0	Specialty chemicals	na	na	na	na	na	na	na
45	47	**PPG Industries**	1,150	3.4	20.0	Glass products	138	-25.4	18.5	12.0	1,092	19.3	12.6
46	49	**Olin**	1,117	12.1	46.1	Basic chemicals	na	na	na	na	na	na	na
47	37	**Texaco**	1,114	-23.9	3.2	Petroleum	na	na	na	na	na	na	na
48	41	**BP America**	1,038	-19.8	6.6	Petroleum	26	-59.4	1.8	2.5	na	na	na
49	52	**Henkel**	1,010	14.6	100.0	Specialty chemicals	na	na	na	na	na	na	na
50	—	**Cytec**	1,008	-3.5	100.0	Basic chemicals	na	na	na	na	na	na	na

Rank 1993	Rank 1992		Chemical sales 1993 ($ millions)	Change from 1992	Chemical sales as % of total sales	Industry classification	Chemical operating profits[a] ($ millions)	Change from 1992	Chemical operating profits as % of total profits	Operating profit margin[b]	Identifiable chemical assets ($ millions)	Chemical assets as % of total assets	Operating return on chemical assets[c]
51	52	**H. B. Fuller**[g]	$975	4.5%	100.0%	Specialty chemicals	$54	–25.1%	100.0%	5.5%	$565	100.0%	9.5%
52	—	**Geon**	973	8.7	100.0	Basic chemicals	24	–384.7	100.0	2.5	721	100.0	3.4
53	50	**Tenneco**	914	–3.9	6.9	Diversified	83	6.4	6.7	9.1	721	4.7	11.5
54	—	**Hanson**	911	12.2	12.6	Diversified	na	na	na	na	na	na	na
55	51	**Engelhard**	910	–4.1	42.3	Diversified	137	7.2	81.5	15.0	788	61.6	17.4
56	57	**Uniroyal Chemical**	908	6.1	100.0	Specialty chemicals	110	0.1	100.0	12.1	1,225	100.0	8.9
57	54	**CF Industries**	906	0.8	100.0	Agrochemicals	–21	def	def	def	951	100.0	–6.7
58	48	**IMC Fertilizer**[f]	897	–15.2	100.0	Agrochemicals	19	–90.1	100.0	2.1	2,056	100.0	0.9
59	54	**Farmland Industries**[h]	893	–0.6	18.9	Agricultural supplies	49	–55.3	63.6	5.5	325	18.9	15.1
60	—	**Wellman**	842	1.7	100.0	Basic chemicals	76	–31.3	100.0	9.1	1,015	100.0	7.5
61	32	**BF Goodrich**	830	–53.3	45.6	Basic chemicals	53	92.0	62.6	6.4	687	29.1	7.7
62	62	**CBI Industries**	826	10.7	49.4	Construction	113	4.8	95.7	13.6	na	na	na
63	69	**Arcadian Partners**	799	34.8	100.0	Agrochemicals	69	–10.0	100.0	8.6	1,015	100.0	6.8
64	65	**Fina**	793	12.3	23.2	Petroleum	60	–39.4	117.3	7.6	402	16.0	15.0
65	59	**Aristech**	788	–1.4	100.0	Basic chemicals	na	na	na	na	na	na	na
66	61	**Georgia Gulf**	769	–1.4	100.0	Basic chemicals	111	–14.2	100.0	14.4	405	100.0	27.3
67	66	**Vista Chemicals**[f]	701	3.9	100.0	Basic chemicals	na	na	na	na	na	na	na
68	56	**NL Industries**	697	–22.0	86.6	Basic chemicals	36	–55.9	57.9	5.2	1,008	83.6	3.6
69	64	**Betz Laboratories**	685	–3.1	100.0	Specialty chemicals	101	–22.8	100.0	14.8	521	100.0	19.4
70	60	**Freeport-McMoRan**	619	–22.5	38.5	Agrochemicals	–56	def	def	def	1,194	32.2	–4.7
71	71	**Sigma-Aldrich**	613	10.8	82.9	Specialty chemicals	149	8.5	89.7	24.2	658	87.4	22.6
72	67	**Loctite**	613	0.8	100.0	Specialty chemicals	na	na	na	na	na	na	na
73	71	**Kerr-McGee**	556	8.0	16.9	Petroleum	70	–11.4	35.2	12.6	733	20.7	9.5
74	70	**Intl. Specialty Products**	548	–3.9	100.0	Specialty chemicals	65	–39.6	100.0	11.9	na	na	na
75	75	**GenCorp**	519	7.7	27.2	Rubber products	47	4.4	38.8	9.1	na	na	na
76	80	**Sterling Chemical**	519	20.5	100.0	Basic chemicals	15	–12.4	100.0	3.0	540	100.0	2.9
77	73	**Union Camp**	519	3.7	16.6	Diversified	49	56.9	23.1	9.4	385	8.2	12.7
78	68	**Merck**	510	–14.2	4.9	Drugs	na	na	na	na	na	na	na
79	73	**Hüls America**	500	0	100.0	Specialty chemicals	na	na	na	na	na	na	na
80	76	**Aluminum Co. of America**	479	0.7	5.3	Nonferrous metals	na	na	na	na	na	na	na
81	63	**Unocal**	460	–37.2	5.5	Petroleum	65	75.7	10.6	14.1	387	4.2	16.8
82	77	**Ferro**	449	–4.2	42.1	Specialty materials	24	20.2	24.9	5.3	238	37.2	10.0
83	79	**Stepan**	439	0.7	100.0	Specialty chemicals	20	–35.7	100.0	4.5	300	100.0	6.5
84	82	**Borden Chemicals**	433	7.8	100.0	Basic chemicals	17	–63.9	100.0	3.8	444	100.0	3.7
85	—	**Rexene**	429	3.5	100.0	Basic chemicals	15	34.2	100.0	3.4	430	100.0	3.4
86	85	**Lonza**	420	10.5	100.0	Specialty chemicals	na	na	na	na	na	na	na
87	83	**Crompton & Knowles**	407	3.1	73.0	Specialty chemicals	68	7.3	72.4	16.7	282	77.6	24.2
88	79	**Mallinckrodt**	395	–10.3	22.0	Specialty chemicals	na	na	na	na	na	na	na
89	81	**Sun Co.**	389	–5.7	4.2	Petroleum	na	na	na	na	na	na	na
90	84	**Vulcan Materials**	377	–3.8	33.2	Nonmetallic minerals	17	–66.1	12.9	4.6	na	na	na
91	87	**Petrolite**[i]	333	10.3	94.5	Specialty chemicals	30	21.7	94.1	8.9	259	86.0	11.5
92	81	**Mississippi Chemical**	289	20.6	74.8	Farm cooperative	23	–27.7	473.5	7.8	287	89.4	7.9
93	86	**First Mississippi**[f]	285	–9.3	66.3	Agrochemicals	38	–4.6	155.8	13.2	168	50.7	22.5
94	88	**Calgon Carbon**	269	–9.7	100.0	Basic chemicals	33	–29.2	100.0	12.3	337	100.0	9.8
95	90	**Georgia-Pacific**	267	11.3	2.2	Wood products	na	na	na	na	na	na	na
96	89	**Agricultural Minerals**	260	6.7	100.0	Agrochemicals	53	–5.3	100.0	20.4	286	100.0	18.5
97	100	**Terra Industries**	229	82.4	18.5	Agrochemicals	29	93.9	58.5	12.5	na	na	na
98	93	**Nova**	222	–1.4	100.0	Basic chemicals	na	na	na	na	na	na	na
99	95	**Cambrex Corp.**	197	9.9	100.0	Specialty chemicals	17	20.4	100.0	8.4	167	100.0	10.0
100	94	**Quaker Chemical**	195	–8.2	100.0	Specialty chemicals	17	–8.5	100.0	8.5	133	78.0	12.5

a Operating profit is sales less administrative expenses and cost of sales. **b** Chemical operating profit as a percentage of sales. **c** Chemical operating profit as a percentage of identifiable chemical assets. **d** Chemical sales include significant amounts of nonchemical products. **e** Fiscal year ended Sept. 30. **f** Fiscal year ended June 30. **g** Fiscal year ended Nov. 30. **h** Fiscal year ended Aug. 31. **i** Fiscal year ended Oct. 31. **na** = not available. **def** = deficit.

Chemical sales, operating profits, assets, and profitability rankings for Top 100 chemical producers

	Chemical sales			Chemical operating profits			Chemical operating profit margin			Identifiable chemical assets			Return on chemical assets		
		Rank			Rank			Rank			Rank			Rank	
$ Millions	1993	1993	1992	1993	1993	1992	1993	1993	1992	1993	1993	1992	1993	1993	1992
Agricultural Minerals	$ 260	96	89	$ 53	50	56	20.4%	3	4	$ 286	59	63	18.5%	8	11
Air Products	2,906	18	18	417	8	6	14.3	11	11	3,646	11	10	11.4	26	21
Akzo	2,241	26	27	196	23	32	8.8	37	62	na	—	—	na	—	—
AlliedSignal	2,791	20	21	309	15	20	11.1	29	49	2,502	16	16	12.4	23	38
Aluminum Co. of America	479	80	76	na	—	—	na	—	—	na	—	—	na	—	—
American Cyanamid	1,411	37	24	na	—	16	na	—	43	na	—	21	na	—	17
Amoco	3,773	12	12	321	14	—	8.5	42	—	3,938	10	—	8.2	43	—
Arcadian Partners	799	63	69	69	43	50	8.6	41	29	1,015	34	49	6.8	51	24
Arco Chemical	3,192	16	15	na	—	8	na	—	20	na	—	9	na	—	28
Aristech	788	65	59	na	—	—	na	—	—	na	—	—	na	—	—
Ashland Oil	2,586	22	23	108	36	45	4.2	64	72	958	37	39	11.3	27	47
BASF	4,037	9	9	na	—	—	na	—	—	na	—	—	na	—	—
Betz Laboratories	685	69	64	101	38	33	14.8	9	8	521	48	53	19.4	7	5
Borden Chemicals	433	84	82	17	67	59	3.8	66	43	444	49	54	3.7	56	45
BP America	1,038	48	41	26	60	53	2.5	69	67	na	—	—	na	—	—
Cabot	1,192	43	44	149	28	28	12.5	20	26	1,117	30	35	13.3	18	26
Calgon Carbon	269	94	88	33	57	58	12.3	23	16	337	55	58	9.8	35	25
Cambrex Corp.	197	99	95	17	67	77	8.4	45	57	167	64	67	10.0	33	49
CBI Industries	826	62	62	113	33	42	13.6	15	21	na	—	40	na	—	35
CF Industries	906	57	54	–21	73	49	def	—	54	951	38	43	def	—	44
Chevron	2,708	21	17	225	21	37	8.3	46	71	2,457	17	14	9.2	38	61
Ciba-Geigy	2,519	23	22	na	—	—	na	—	—	na	—	—	na	—	—
Crompton & Knowles	407	87	83	68	44	54	16.7	5	15	282	60	60	24.2	2	7
Cytec	1,008	50	—	na	—	—	na	—	—	na	—	—	na	—	—
Dow Chemical	12,524	2	2	773	2	5	6.2	53	68	12,530	2	2	6.2	53	60
Dow Corning	2,044	28	29	236	20	23	11.5	28	46	3,265	13	17	7.2	50	47
DuPont	15,603	1	1	750	3	1	4.8	59	52	13,957	1	1	5.4	54	46
Eastman Chemical	3,903	10	10	476	7	—	12.2	24	—	4,341	8	—	11.0	28	—
Elf Atochem	1,700	35	34	na	—	—	na	—	—	na	—	—	na	—	—
Engelhard	910	55	51	137	31	36	15.0	8	24	788	39	42	17.4	12	17
Ethyl	1,938	29	35	168	27	21	8.6	40	31	2,009	21	26	8.3	40	20
Exxon	10,024	3	3	638	5	3	6.4	51	63	8,478	3	3	7.5	48	56
Farmland Industries	893	59	54	49	52	40	5.5	54	38	325	56	59	15.1	15	1
Ferro	449	82	77	24	62	72	5.3	56	69	238	62	64	10.0	33	53
Fina	793	64	65	60	47	44	7.6	49	22	402	52	51	15.0	16	13
First Mississippi	285	93	86	38	55	61	13.2	17	33	168	63	66	22.5	4	6
FMC	1,837	32	31	197	22	22	10.7	30	41	1,522	24	25	13.0	19	22
Freeport-McMoRan	619	70	60	–56	74	76	def	—	77	1,194	29	33	def	—	69
H. B. Fuller	975	51	52	54	49	52	5.5	54	58	565	46	48	9.5	36	28
GenCorp	519	75	75	47	54	60	9.1	33	50	na	—	—	na	—	—
General Electric	5,042	6	7	834	1	2	16.5	6	19	8,181	4	4	10.2	32	50
Geon	973	52	—	24	62	—	2.5	69	—	721	41	—	3.4	58	—
Georgia Gulf	769	66	61	111	34	34	14.4	10	14	405	51	56	27.3	1	3
Georgia-Pacific	267	95	90	na	—	—	na	—	—	na	—	—	na	—	—
BF Goodrich	830	61	32	53	50	69	6.4	51	79	687	44	28	7.7	46	66
W. R. Grace	2,895	19	13	392	10	10	13.5	16	35	2,115	18	15	18.5	8	14
Great Lakes Chemical	1,792	34	36	415	9	11	23.2	2	2	1,901	22	—	21.8	5	—
Hanson	911	54	—	na	—	—	na	—	—	na	—	—	na	—	—
Henkel	1,010	49	52	na	—	—	na	—	—	na	—	—	na	—	—
Hercules	1,843	31	28	252	19	19	13.7	14	40	1,375	25	22	18.3	10	19

	Chemical sales			Chemical operating profits			Chemical operating profit margin			Identifiable chemical assets			Return on chemical assets		
		Rank			Rank			Rank			Rank			Rank	
$ Millions	1993	1993	1992	1993	1993	1992	1993	1993	1992	1993	1993	1992	1993	1993	1992
Hoechst Celanese	$6,347	4	4	$561	6	9	8.8%	37	60	na	—	—	na	—	—
Hüls America	500	79	73	na	—	—	na	—	—	na	—	—	na	—	—
Huntsman Chemical	1,850	30	—	na	—	—	na	—	—	na	—	—	na	—	—
ICI Americas	3,565	13	—	188	25	—	5.3	56	—	na	—	—	na	—	—
IMC Fertilizer	897	58	48	19	66	24	2.1	71	10	$2,056	19	20	0.9%	62	37
International Flavors	1,189	44	46	na	—	17	na	—	3	na	—	31	na	—	7
Intl. Specialty Products	548	74	70	65	45	42	11.9	27	5	na	—	—	na	—	—
Kerr-McGee	556	73	71	70	42	48	12.6	19	17	733	40	44	9.5	36	39
Loctite	613	71	67	na	—	38	na	—	—	na	—	50	na	—	10
Lonza	420	86	85	na	—	—	na	—	—	na	—	—	na	—	—
Lubrizol	1,526	36	38	190	24	25	12.5	20	29	1,055	32	41	18.0	11	7
Lyondell Petrochemical	1,326	39	39	57	48	30	4.3	63	48	688	43	—	8.3	40	—
Mallinckrodt	395	88	79	na	—	—	na	—	—	na	—	—	na	—	—
Merck	510	78	68	na	—	47	na	—	23	na	—	47	na	—	22
Miles	3,053	17	19	na	—	—	na	—	—	na	—	—	na	—	—
Mississippi Chemical	289	92	81	23	64	65	7.8	48	26	287	58	61	7.9	45	39
Mobil	3,533	14	11	25	61	29	0.7	72	73	3,451	12	11	0.7	63	62
Monsanto	5,651	5	5	731	4	4	12.9	18	42	5,312	6	6	13.8	17	28
Morton International	1,274	40	42	135	32	27	10.6	31	24	1,273	26	30	10.6	29	27
Nalco Chemical	1,389	38	40	263	18	18	18.9	4	5	1,212	28	29	21.7	6	11
National Starch	1,808	33	30	288	16	14	15.9	7	17	1,672	23	23	17.2	13	16
NL Industries	697	68	56	36	56	39	5.2	58	37	1,008	36	27	3.6	57	57
Nova	222	98	93	na	—	—	na	—	—	na	—	—	na	—	—
Occidental Petroleum	4,065	8	8	184	26	46	4.5	61	76	5,780	5	5	3.2	60	68
Olin	1,117	46	49	na	—	—	na	—	—	na	—	38	na	—	—
Petrolite	333	91	87	30	58	71	8.9	36	56	259	61	65	11.5	24	33
Phillips Petroleum	2.308	25	26	97	39	63	4.2	64	78	2,011	20	19	4.8	55	67
PPG Industries	1,150	45	47	138	30	25	12.0	26	13	1,092	31	37	12.6	21	15
Praxair	2,438	24	20	341	12	15	14.0	13	47	3,255	14	12	10.5	30	54
Quaker Chemical	195	100	94	17	67	73	8.5	42	55	133	65	68	12.5	22	31
Rexene	429	85	—	15	71	—	3.4	67	—	430	50	—	3.4	58	—
Rhône-Poulenc	2,200	27	25	na	—	—	na	—	—	na	—	—	na	—	—
Rohm and Haas	3,269	15	16	267	17	12	8.2	47	45	3,200	15	13	8.3	40	35
Shell Oil	3,875	11	14	328	13	—	8.5	42	—	4,312	9	—	7.6	47	—
Sigma-Aldrich	613	71	71	149	28	31	24.2	1	1	658	45	52	22.6	3	4
Solvay America	1,200	42	45	na	—	—	na	—	—	na	—	—	na	—	—
Stepan	439	83	79	20	65	65	4.5	61	59	300	57	62	6.5	52	42
Sterling Chemical	519	75	80	15	71	73	3.0	68	70	540	47	46	2.9	61	63
Sun Co.	389	89	81	na	—	—	na	—	—	na	—	—	na	—	—
Tenneco	914	53	50	83	40	81	9.1	33	—	721	41	45	11.5	24	—
Terra Industries	229	97	100	29	59	—	12.5	20	—	na	—	—	na	—	—
Texaco	1,114	47	37	na	—	80	na	—	—	na	—	—	na	—	—
Union Camp	519	75	73	49	52	65	9.4	32	63	385	54	57	12.7	20	51
Union Carbide	4,640	7	6	354	11	13	7.6	49	61	4,419	7	7	8.0	44	58
Uniroyal Chemical	908	56	57	110	35	40	12.1	25	31	1,225	27	34	8.9	39	52
Unocal	460	81	63	65	45	64	14.1	12	66	387	53	55	16.8	14	55
Vista Chemicals	701	67	66	na	—	—	na	—	—	na	—	—	na	—	—
Vulcan Materials	377	90	84	17	67	57	4.6	60	26	na	—	—	na	—	—
Wellman	842	60	—	76	41	—	9.1	33	—	1,015	34	—	7.5	49	—
Witco	1,233	41	58	108	36	51	8.8	37	52	1,037	33	36	10.4	31	58

Note: There are 74 companies ranked for operating profit, 72 for operating profit margins, 65 for chemical assets, and 63 for return on chemical assets. **na** = not available. **def** = deficit.

Firms that are classified as chemical companies—that is, with 50% or more of sales coming from chemicals—made up 42% of the sales of the total 100 in 1993, the same percentage as for the 1992 ranking. But perhaps because of the inclusion of ICI Americas, foreign-owned firms—most of which could be classified as chemical companies—now account for 20% of the total sales of the Top 100, up from 16% in the 1992 ranking. The increase in the share held by the U.S. units of foreign companies came at the expense of oil and gas producers that also make chemicals, which dropped from 21% to 18%, and the diversified and other category, which fell from 21% to 20%. In the past five years, the foreign-owned share has risen from 14%, while the share from the oil companies has dropped from 20% and that from the diversifieds fell from 24%.

In terms of the sales ranking for the chemical producers, there was little change in the top 10 list, with DuPont still in first place. All of the top 10 companies for 1993 were in the top 10 in the 1992 listing, although General Electric and Union Carbide switched places, with GE rising to sixth place from seventh and Union Carbide falling to seventh from sixth.

However, since GE's sales, published in its annual report as "materials," include significant amounts of nonchemical products, its chemical sales probably are, in actuality, lower than Carbide's.

The reliance on annual reports for chemical sales data causes some problems. For instance, while chemical sales for some companies such as GE and American Cyanamid are overstated, sales for some other companies like PPG Industries and Witco are probably understated.

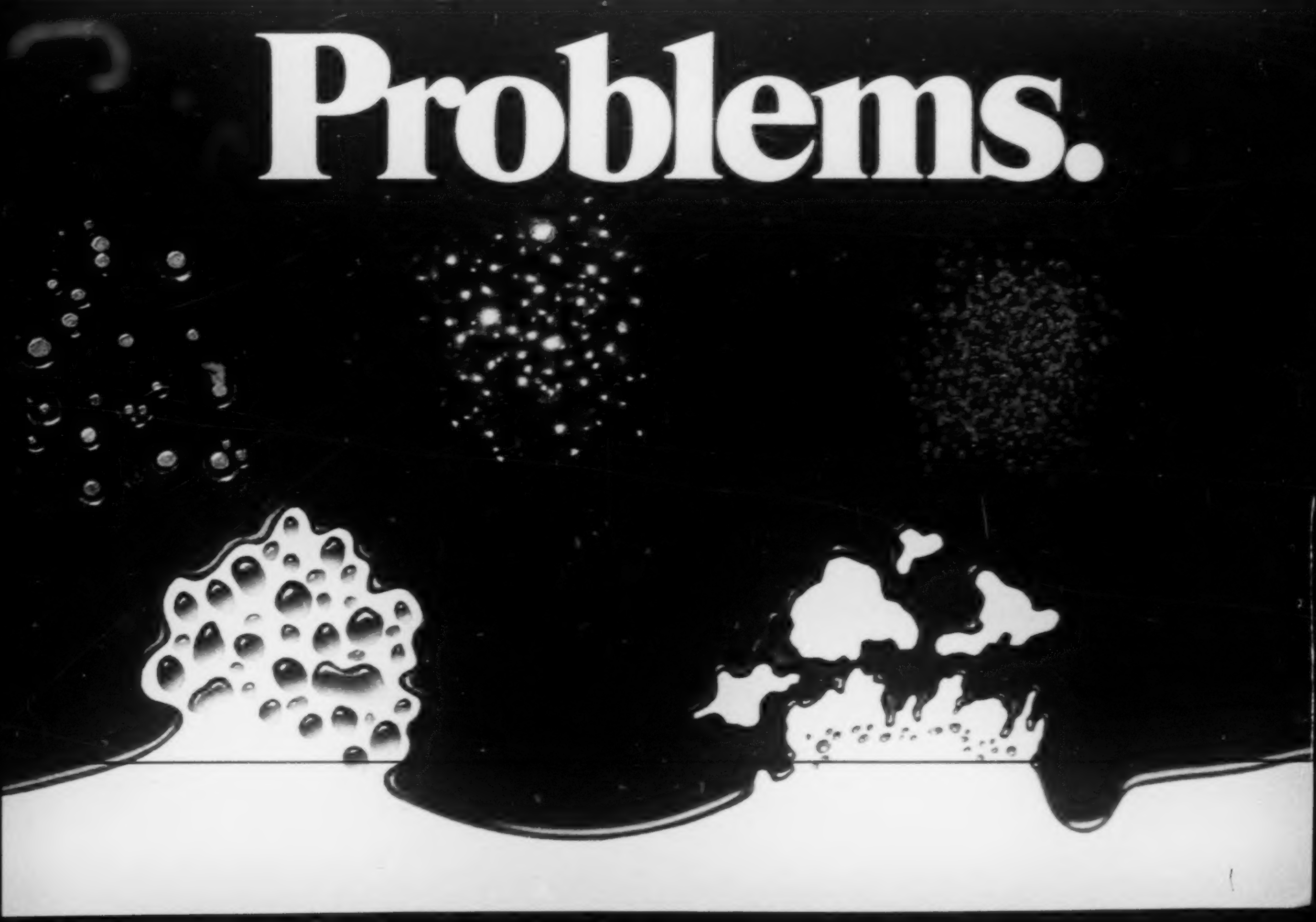
Annual reports are also used for the subsidiary rankings for operating profits, chemical assets, and profitability, and this year a number of companies—many with high profitability—did not respond to requests for annual reports and thus are not included in these rankings. Among these companies are International Flavors & Fragrances, which had ranked third in operating profit margin in the 1992 listing; Arco Chemical; Loctite; and Mallinckrodt, which recently changed its name from Imcera.

Among the rankings other than that for sales, GE took first place for chemical operating profits with $834 million. GE was followed by Dow Chemical ($773 million), DuPont ($750 million), Monsanto ($731 million), and Exxon ($638 million).

For operating profit margin, the leader was Sigma-Aldrich (24.2%), followed by Great Lakes Chemical (23.2%), Agricultural Minerals (20.4%), Nalco Chemical (18.9%), and Crompton & Knowles (16.7%).

As it did for sales, DuPont took first place in chemical assets with almost $14.0 billion. Dow was in second place with $12.5 billion in assets, followed by Exxon with about $8.48 billion, GE with $8.18 billion, and Occidental Petroleum with $5.78 billion.

Georgia-Gulf had the best return on chemical assets at 27.3%. This was followed by Crompton & Knowles (24.2%), Sigma-Aldrich (22.6%), First Mississippi (22.5%), and Great Lakes Chemical (21.8%). ☐



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CHEMICAL & ENGINEERING NEWS
C&EN
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CHEMICAL COMPANY EARNINGS RISE SUBSTANTIALLY IN FIRST QUARTER PAGE 30

Fine & Intermediate Chemicals

Producers respond to environmental, market pressures Page 10

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CHEMICAL & ENGINEERING NEWS
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MAY 16, 1994

NEWS OF THE WEEK

- If a promising new Merck drug to treat AIDS proves out, work by the company to develop a low-cost, high-yield process may be crucial for commercialization. **Page 6**
- NSF awards nine U.S. cities $15 million each to improve science, math, and technology education programs for inner-city children. **Page 7**
- Arco announces plan to raise up to $1 billion by offering debt securities linked to stock in Lyondell Petrochemical, opening path to possible divestiture of the Houston-based company. **Page 7**
- In a move to advance the links between computer science and biotechnology drug design, two major computer industry executives make a substantial investment in a startup drug-development firm. **Page 8**
- U.S. and U.K. researchers announce construction of a reversible "molecular switch" that is triggered by either pH change or electrochemical oxidation-reduction, based on a molecular "bead" encircling a "thread." **Page 8**
- Initiatives to advance development of science and technology in Africa are discussed at a forum in Washington, D.C. **Page 9**

COVER: Workers at AlliedSignal Performance Chemicals, Morristown, N.J., produce oxime intermediates to special order

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BUSINESS

First-quarter results are good news for major chemical companies—solid sales contributed to strong earnings and production rose, as did profitability. **Page 30**

Restructuring is theme of Chemical Management & Resources Association meeting, and reaction to the topic is as varied as the way the term is defined. **Page 34**

Unilever is introducing a "new generation" concentrated detergent to European markets—one with a formulation unusual enough to spawn two legal actions in the Netherlands. **Page 35**

GOVERNMENT

House passes NSF reauthorization bill—one of many bills being considered by Congress—that allows for 4.2% growth in 1995 and 2.6% growth in 1996; the measure goes to the Senate next. **Page 38**

Agricultural chemical makers note that Congress is beginning to consider usefulness of risk assessment in setting regulatory priorities and formulating regulations on the use of chemicals. **Page 40**

SCIENCE/TECHNOLOGY

Stanford University chemists have created a random library of single amino acid mutants of myoglobin to discover new ligand binding pathways in the protein. **Page 49**

Handheld electronic chemical calculator currently under development could change the way that chemistry is taught and become an accessory to research. **Page 50**

NEWS FOCUS

Producers of fine and intermediate chemicals face major changes in their markets, sparked by the increasing emphasis on chiral drugs and tougher environmental regulations. Page 10

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LETTERS

A human chain reaction

Last fall, I attended the annual retirees reunion of Dow Corning. It was a special year being the 50th anniversary of Dow Corning. Seated next to me was Frank Hyde, the chemist who made Dow Corning possible. It was a special year for him, too, his 90th birthday anniversary. The conversation led to our experiences at Harvard University and the powerful impact Harvard had on organic chemistry in the U.S. Frank's commentary helped sharpen my memory of stories about Harvard that I had heard years before from another Frank—F. C. Whitmore—when I was one of his last graduate students at Penn State.

Whitmore likened his experience at Harvard to being part of a "human chain reaction." He was one of a small group of chemistry students who, in today's sports parlance, I would name the "Fabulous Four." The other three were Roger Adams, Henry C. Gilman, and James B. Conant. They were not all in exactly the same graduating class, but as both undergraduate students at Harvard and as graduate students in organic chemistry their student careers had considerable overlap. One of their most influential teachers, Elmer P. Kohler, initiated the chain reaction. He instilled in all four the love of teaching. He constantly drew on their unusual talents to get them to teach each other. When necessary, he deflated their not inconsiderable egos by asking probing questions that none could answer. Probably at no other time in the history of chemistry teaching did four such talented students fill the halls of learning of a single school at the same time. The chain reaction gathered strength.

In those years just after the turn of the century, it was de rigueur for chemistry students to go to Germany for doctoral studies. The combination of a satisfactory undergraduate experience at Harvard and the looming prospect and then the reality of the First World War kept all four away from Germany and at school in the U.S.

In 1905, Adams was the first of the four to start at Harvard as an undergraduate and to receive a Ph.D. degree (1912). In 1916, he went to the University of Illinois and became head of the department of chemistry there in 1926. Under his marvelous tutelage, there was a great outpouring of well-trained organic chemists from Illinois, most of whom would play important roles as industrial chemists.

The youngest of the four was Gilman, who received a B.S. degree from Harvard in 1915 and a Ph.D. degree in 1918. He, too, became a professor of chemistry—at Iowa State. In my day, it was a requirement of graduate students to own the twin green books by Gilman. He would become a good personal friend of mine since we both shared a love of organosilicon chemistry. He was the most long-lived of the four, with a life of over 90 years, which he devoted to research and teaching. Being a "Gilman student" was a term of highest accolade. Gilman was the first recipient of the American Chemical Society's Frederic Stanley Kipping Award in Organosilicon Chemistry, sponsored by Dow Corning Corp., for excellence in organosilicon research. He had a fond and friendly rivalry with Whitmore in this research arena during the 1940s. Whitmore was very anxious to publish a communication in the *Journal of the American Chemical Society* of my first research on *tert*-butyltrichlorosilane "before Henry scoops us."

Conant was the "Harvard Man of the Century." He received an A.B. degree in 1913, a Ph.D. degree in 1916, and stayed on. I feel as if I knew him personally because my love of organic chemistry was first nurtured when we used his most excellent textbook for study at the University of Scranton in 1939. Conant's legendary prowess as an educator was continually evident. He became a full professor, and then in 1933, went on to be a renowned member of that elite group—Harvard presidents. In 1948, his name was floated quite seriously as a possible candidate for the U.S. Presidency. And he is one of the few chemists whose face has graced the cover of *Time* magazine.

Correction

- May 2, page 9: A business concentrate on Shanghai Petrochemical misstated the company's sales and earnings. Sales increased 43% to $872 million in 1993, not $871,560. Earnings rose 90% to $100 million, not $100,000.

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Market, Environmental Pressures Spur Change In Fine Chemicals Industry

Increasing emphasis on chiral drugs, more stringent environmental rules are among economic and technical issues confronting producers

Stephen C. Stinson,
C&EN Northeast News Bureau

Makers of fine chemicals have much in common with other parts of the chemical industry. Although ways of doing business may be somewhat different, the major concerns—including markets, new product development, process economics, environmental stewardship, and attention to core technologies—are the same.

For the fine chemicals industry, these issues were ratcheted to a new level of intensity at ChemSpec Europe '94, the international meeting of fine chemicals producers held last month in Manchester, England. Indeed, developments surfacing in Manchester create a picture of an industry not only responding to change but generating it as well.

From a business standpoint, for example, the fortunes of the fine chemicals industry are especially sensitive to changes in the pharmaceutical industry, which consumes about half the fine chemicals industry's output. One development about to make its mark is the growing emphasis on chiral drugs. Single enantiomers of chiral drugs have long been a focus of medicinal chemists and process engineers, but observers in Manchester told C&EN that significant orders for compounds have at last begun to arrive.

Environmental matters, too, affect the industry. Fine chemicals producers worldwide naturally must accommodate their own governments' increasingly stringent environmental regulations. But in some of those countries, environmental regulations are still less exacting than those of the U.S. In their own self-interest, firms outside the U.S. realize that most of their customers are nevertheless in the U.S., and American customers hesitate to appear linked to suppliers who might have environmental problems.

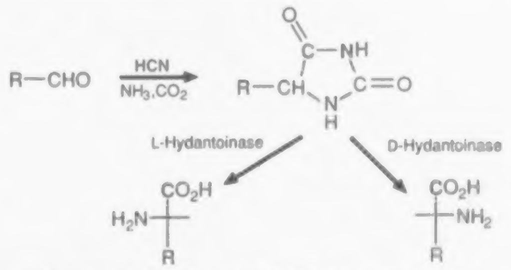
Technologically, the fine chemicals industry is a substantial market for firms that supply intermediates, catalysts, and equipment. Such goods help producers cut production steps and costs, as well as decrease the number of waste streams to be treated. At the same time, fine chemicals producers are constantly expanding and deepening the particular chemistries at which they excel.

Analyst Enrico T. Polastro of Arthur D. Little International, Brussels, estimates the value of worldwide fine chemicals sales in the range of \$26 billion to \$34 billion. This includes bulk active ingredients as well as intermediates for end uses such as drugs and pesticides. Drugs alone take \$15 billion to \$17 billion worth, Polastro says, perhaps a 50 to 60% share.

Within the drug market, dollar sales for single enantiomers of chiral drugs are likely to grow at the expense of racemates, says analyst Ray Ceriotti of Technology Catalysts International Corp.,

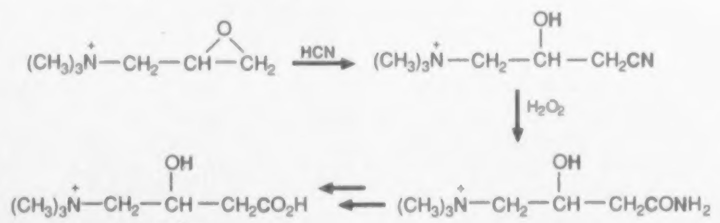
Hydrogen cyanide is core technology for amino acids

Hydantoins yield enantiomeric amino acids . . .



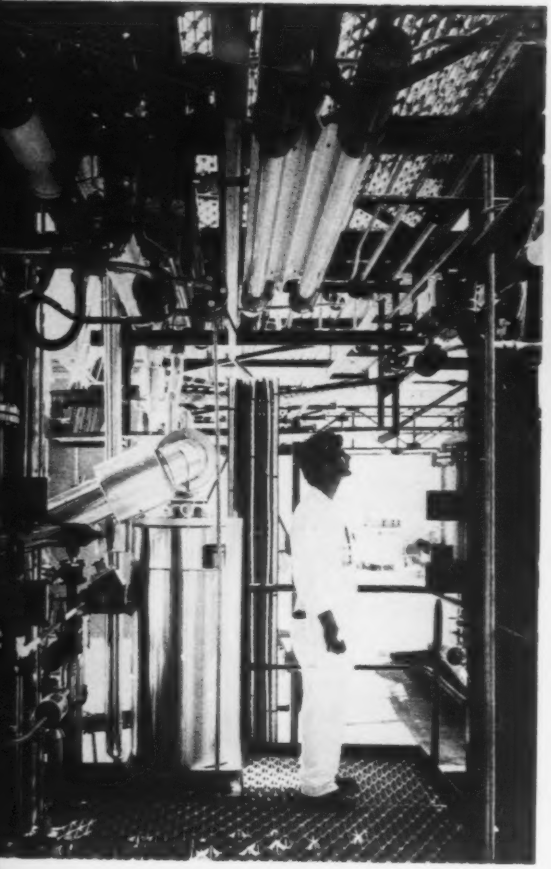
R = $C_6H_5CH_2$—, $(CH_3)_2CH$—, $CH_3CH_2CH_2$—, $CH_3CH_2CH_2CH_2$—, $(CH_3)_2CHCH_2$—, $C_6H_5CH_2CH_2$—, CH_3SCH_2—, or CH_3—

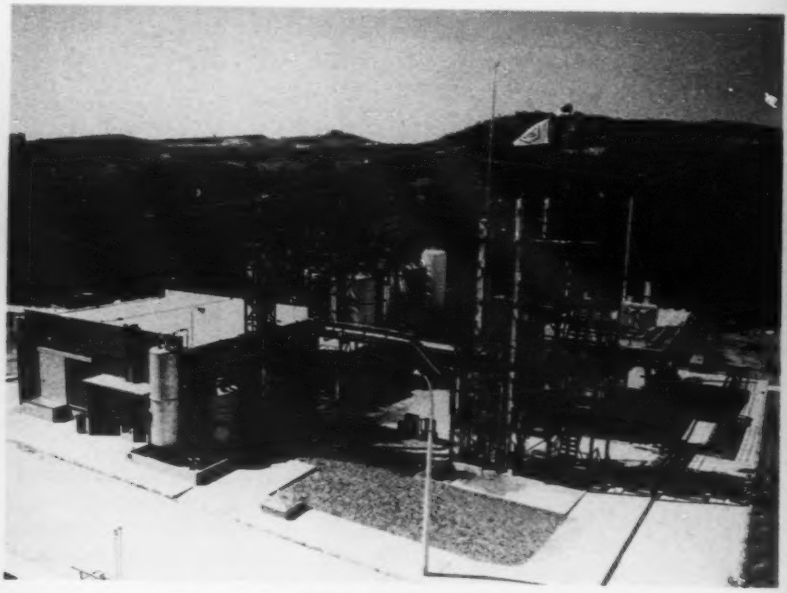
. . . and an epoxide opening gives carnitine



L-Carnitine

Source: Degussa





Drug producer Hovione reduced solvent use and built a solvent and raw material recovery unit (above) in Loures, Portugal, that won an environmental prize from the European Union. Plant operator (left) monitors methanol recovery columns.

Falls Church, Va. Also, sales of enantiomeric drugs will grow faster than sales of fine chemicals generally, he adds, because of the greater added value in production.

In light of the heavy weighting toward drugs, Polastro predicts thoroughgoing changes in the worldwide fine chemicals industry over the next 15 years. Polastro sees three alternative courses of events unfolding as health care reform proceeds in many countries, and he assigns a probability to the development of each over time.

He labels these alternatives "business-as-usual," "cost cutting," and "rational." He rejects the business-as-usual alternative out of hand, assigning the present state of affairs only a 20% chance of persisting to 1995 and vanishing completely by 1997.

By cost cutting, Polastro means the employment of drastic measures to contain costs, with companies and institutions the targets. Although marked by rigid government control, this course of action would involve only incremental impact and extent of health care reforms. Rather, this narrow, rigid, price-based policy would put the burden mainly on drugs, creating demand for the cheapest available ones without regard to cost-benefit analyses.

Any cost-cutting phase would hit fine chemical makers severely. Because drug companies would be searching for all possible ways to cut production expenses, their fine chemicals suppliers would feel some of the pain.

But the cost-cutting policy would change neither patients' and institutions' drug-buying procedures essentially nor the current structure of drug companies and distributors, or hospital, chain, and neighborhood pharmacies. Some governments—and here Polastro thinks of Spain—may set up their own generic drug factories. Polastro sees the cost-cutting scenario as likeliest in the short term, with a 50% probability of being in place in 1995, rising to 75% by 1997.

In the long term, Polastro is more optimistic and predicts evolution toward a "rational" system. Such a system would be based on cost-benefit relationships, he thinks, rather than just on price. Adoption of the rational course would mean liberalization on the part of government agencies, but it would also bring a profound restructuring of the health care system as suppliers move to adapt to and compete in such a system. Drug companies and their fine chemicals suppliers would benefit as they develop products in this climate. Polastro sees the probability of the rational approach rising slowly and uniformly year by year to 100% by 2010 as reliance on cost cutting recedes toward zero.

Exploiting core technologies

At the Manchester meeting, several fine chemicals firms showed off their core technologies. These are specific chemistries that companies concentrate on in addition to their abilities to draw on all of chemistry where needed for multistep syntheses. Speakers from some companies described those firms' core technologies at the symposium, while other companies introduced new products based on their core technologies at the exposition.

For example, group leader John F. McGarrity at Lonza's research center in Visp, Switzerland, described the company's expertise in hydrogen cyanide and its derivatives, ketene and diketene (4-methyleneoxetan-2-one), and pyridines. He emphasized competitiveness through exploitation of an existing raw materials base and cross-fertilization among different projects.

McGarrity also spoke of the need for "carrier projects" as a means of devel-

C&EN staff photos

Hoechst, Lonza, and Plater Chemicals booths at ChemSpec Europe '94 meeting of fine chemicals producers in Manchester.

oping new core technologies. Carrier projects are those that generate a solid cash product at once, and from which profits pay for deepening the company's experience in that technology thereafter.

In one project, Lonza uses its raw materials position in cyanogen chloride, $Cl—C\equiv N$, to make a compound known as Vince's lactam (2-azabicyclo[2.2.1]hept-5-en-2-one). Named for medicinal chemist Robert Vince, who developed it in 1978 while at the University of Minnesota's College of Pharmacy, Minneapolis, the lactam has found use to make carbocyclic ribose drug analogs, most notably in recent years by Chiroscience of Cambridge, England. Indeed, Ray McCague of Chiroscience has described making the lactam by Diels-Alder reaction of *p*-toluenesulfonyl cyanide and cyclopentadiene, followed by hydrolysis.

McGarrity says that methanesulfonyl cyanide is safer to handle, however, and Lonza used that compound to devise a cyclic process to make Vince's lactam on a 100-kg scale. Methanesulfonyl cyanide comes from reaction of sodium methanesulfinate $[CH_3S(O)O^- Na^+]$ with cyanogen chloride. Hydrolysis of the Diels-Alder product with cyclopentadiene regenerates methanesulfinate, which is recycled to react with more cyanogen chloride.

Examples of Lonza carrier projects are the company's use of methyl or ethyl δ-chloroacetoacetates to make 2-aminothiazoles and biotin. 2-Aminothiazoles are added as side chains to advanced cephalosporin antibiotic nuclei. Biotin is a feed additive. Profits from sales of these compounds are fueling development of other projects based on four-carbon intermediates and on the proprietary diastereoselective hydrogenation catalyst used to make (+)-biotin.

Regarding cross-fertilization, the idea for the biotin hydrogenation came from an analogous hydrogenation to make the antibiotic thienamycin. As McGarrity put it, "The important message here is that from one project has evolved not only a familiarity with a particular class of intermediates, but also one pivotal building block that provides access to a variety of other product classes. In a more general context, the greater the variety of chemical and technical problems tackled and solved within Lonza, the greater will be the reservoir of expertise available to solve the problems posed by new projects."

Chemist Rudolf Vanheertum of Degussa's subsidiary in Antwerp, Belgium, described that firm's use of hydrogen cyanide and cyanogen chloride as core technologies. Degussa's worldwide hydrogen cyanide capacity is 100,000 metric tons per year, made by platinum-catalyzed reaction of methane and ammonia. Chlorination of hydrogen cyanide yields cyanogen chloride. Vanheertum explains that "because transportation of both compounds is practically prohibited by restrictive regulations, Degussa has concentrated on the synthesis and custom manufacturing of fine chemicals in several multipurpose plants."

From hydrogen cyanide itself come cyanohydrins, amino acids, and amines. For example, reaction with benzaldehyde catalyzed by either (*R*)- or (*S*)-oxynitrilase enzyme produces the cyanohydrins (*R*)- or (*S*)-mandelonitrile of high enantiomeric purity.

Also, reaction of hydrogen cyanide with aldehydes together with ammonia gives α-aminonitriles, which can be hydrolyzed to racemic α-amino acids. Alternatively, hydrogen cyanide, ammonia, and carbon dioxide convert aldehydes to hydantoins (4-alkylimidazolidine-2,5-diones), which can be hydrolyzed with D- or L-hydantoinases to yield D- or L-α-amino acids. And opening of the epoxide of glycidyltrimethylammonium chloride by hydrogen cyanide is a step on the way to the amino acid feed additive L-carnitine [(3-carboxy-2-hydroxypropyl)trimethylammonium hydroxide].

As for production of amines, reaction of isophorone (3,5,5-trimethylcyclohex-2-enone) with hydrogen cyanide is a step on the way to isophoronediamine (5-amino-1-aminomethyl-1,3,3-trimethylcyclohexane), which is useful by itself as an epoxy curing agent or can be converted with phosgene to isophorone diisocyanate, a component of light-stable polyurethane coatings. And reaction of hydrogen cyanide with the 2,4,4-trimethyl-1-pentene isomer of diisobutylene is a route to *tert*-octylamine (2-amino-2,4,4-trimethylpentane), which is useful because of the *tert*-alkyl group attached to nitrogen.

Elsewhere in Degussa, chiral amino acids are a core technology apart from their production from hydrogen cyanide. Chemist Matthias Kottenhahn of the company's site in Hanau, Germany, says that Degussa produces and markets amino acid enantiomers through its subsidiary, Rexim, in Courbevoie, France, which Kottenhahn says is the largest amino acid producer in Europe.

In addition to L-amino acids that occur naturally in proteins, Rexim makes D-amino acids and nonproteinogenic ones. For example, leucine dehydrogenase catalyzes transformation of trimethylpyruvic acid to nonnatural L-*tert*-leucine (α-amino-β,β-dimethylalanine), which is a component of an experimental Hoffmann-La Roche agent against atherosclerosis. The reduction occurs at the expense of oxidation of cofactor nicotinamide adenine dinucleotide (NADH) to NAD^+. The reduced cofactor is regenerated in a parallel oxidation of ammonium formate to carbon dioxide by formate dehydrogenase.

D-Amino acids give peptides containing them resistance to hydrolysis, Kottenhahn says. Thus D-valine is a component of the pyrethroid insecticide fluvalinate, and D-alanine is part of the artificial sweetener alitame. And a polymethacrylate resin with its pendant carboxyl groups amidized by terminal amino groups of D-lysine is an additive that aids enantiomeric resolution by inhibiting crystallization of one enantiomer from aqueous solutions.

Ozonolysis is a core technology at Chemie Linz, according to Bernt D. Schober. Schober, manager of new business development in custom manufacture, says the Austrian firm has an ozone capacity of 150 kg per hour from two electric discharge generators.

The ozonolysis method is attractive because there are low emissions to the environment, little wastewater, and no residues from the oxidizing agent. The method is also safe because Chemie Linz follows ozonolysis with reduction before workup, so no hazardous compounds accumulate.

Chemie Linz uses its ozone to make glyoxylic acid and derivatives from dimethyl maleate. Schober notes that the Emery Group of Henkel Corp., Cincinnati, has produced azelaic and pelargonic acids from ozonolysis of oleic acid for almost 40 years.

The fragrance compound piperonal [(3,4-methylenedioxy)benzaldehyde] comes from ozonolysis of naturally occurring isosafrole [1,2-(methylenedioxy)-4-propenylbenzene]. And one step in the synthesis of the cephalosporin antibiotic cefaclor is ozonolysis of the exocyclic double bond of a methylenethiazine derivative to the enol of the ketothiazine.

Schober suggests Chemie Linz may show future interest in the synthesis of difunctional compounds as dialdehydes from cyclic olefins, including β-pinene, and 2,5-dihydrofurans, -thiophenes, and -phospholes. The interest in these starting materials is that two functional groups are obtained per mole of ozone.

Enantiomeric drugs are growing at the expense of racemates

Drug category	Sales, $ billions[a]				% average annual change
	1993	1994	1995	1996	
Achiral	$ 8.4	$ 9.5	$ 9.8	$10.2	7.0%
Racemic	3.9	3.0	2.2	1.4	–29.5
Enantiomeric	22.1	23.0	24.8	26.7	6.6
TOTAL	$34.4	$35.5	$36.8	$38.3	3.7%
ENANTIOMERIC, %	64.3%	64.8%	67.4%	69.7%	

a Data are worldwide sales of final dosage forms for 25 top-selling prescription drugs. **Source:** Technology Catalysts International Corp.

Nitration and nitric acid oxidation is the core technology at Nobel Chemicals, Karlskoga, Sweden, described by Boris Holm. Holm, who is manager of market development and sales, says the challenge is not only the nitration or oxidation itself but also that nitro or nitrate ester products may be explosive.

Such compounds are dangerous, of course, and also transportation to the customer may be complicated by regulations. So if the purpose of the nitro group is as a functional group handle on the route to another nonnitro compound, Holm says, customers could do well to let Nobel carry out further steps and take delivery of that more advanced intermediate.

Nitric acid oxidation of nitrotoluenes to nitrobenzoic acids yields products of purity needed for drug manufacture, Holm says. The *o*-nitrobenzoic acid is tricky, however, because of the danger of forming explosive picric acid.

Nitrobenzaldehydes are intermediates in production of drugs called calcium channel blockers, which are used for treatment of high blood pressure

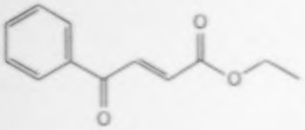
Drug firms have different fine chemicals needs and sourcing strategies

Type of drug firm and examples	Sourcing strategy	Product needs	Product slate
Innovative R&D based (Glaxo, Merck, Hoffmann-La Roche)	Combine in-house production with outsourcing on a case-by-case basis	Customer specific	Broad and related to specific drugs; can include active drugs and intermediates
Branded, multisource (Warner-Lambert, Sterling Winthrop, Zyma)	Rely on merchant market (most drug compounds are freely available and in-house production is rarely cost competitive)	Industry specific	Narrow (for example, in over-the-counter products, only 20 to 30 compounds are used); focus is on active drugs, not intermediates
Generic producers (Lyphomed, Apothecon, Abbott Hospital Products)	Rely on merchant market (keeps capital investment lean; backward integration would reduce flexibility to shift product line)	Industry specific	Broad (more than 400 drugs are available as generic formulations); focus is on active drugs, not intermediates

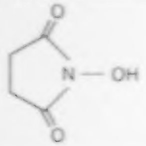
Source: Arthur D. Little International

Fine Chemicals:
New in Pilot Quantities

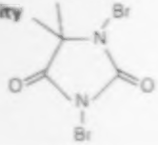
Ethyl benzoyl acrylate



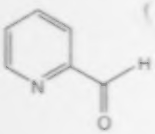
N-Hydroxy succinimide



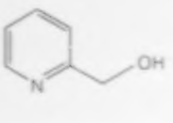
Dibromo dimethylhydantoin
Pharma Quality



Pyridine-2-aldehyde



2-Hydroxy methyl pyridine



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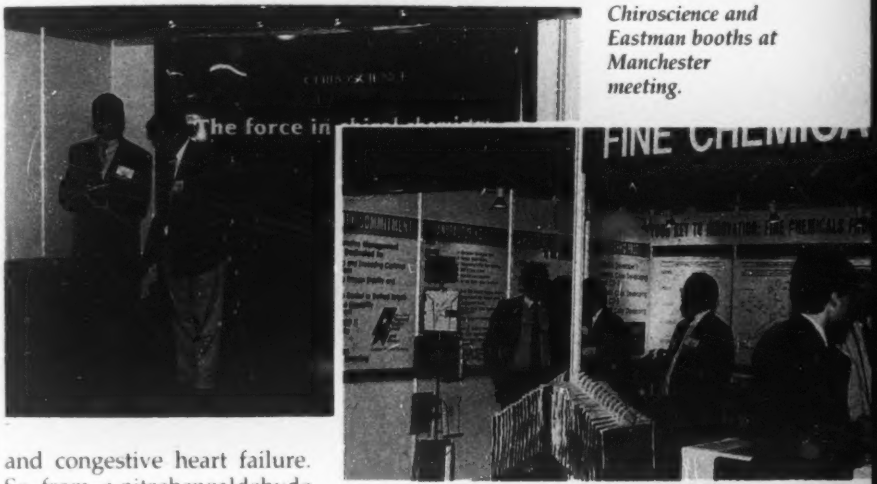


Chiroscience and Eastman booths at Manchester meeting.

and congestive heart failure. So from *o*-nitrobenzaldehyde come the nifedipine and nisoldipine discovered by Bayer. *m*-Nitrobenzaldehyde gives nicardipine (Yamanouchi) and nimodipine and nitrendipine (both Bayer).

Another important intermediate at Nobel is *p*-nitrobenzoic acid, Holm says, used to make the anesthetic procaine, the vitamin folic acid, and *p*-aminobenzoic acid (PAB). PAB is a feed additive, especially for fish farming, and its esters are sunscreens. The *N*-*p*-aminophenylamide of PAB is under study as a replacement for carcinogenic benzidine in dyes. And the diester of PAB with 1,3-propanediol may replace possibly carcinogenic methylenebis(*o*-chloroaniline) (MOCA) as a polyurethane cross-linking agent, if government agencies ban MOCA.

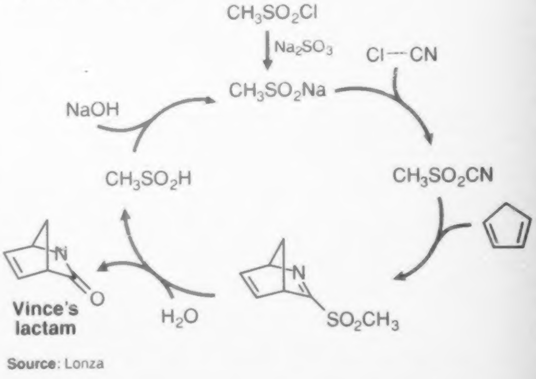
Another new development at Nobel is production of several aminochlorobenzoic acids. The interest there is that Nobel has found an inhibited hydrogenation catalyst from Degussa that reduces nitro groups to amino groups without expelling chlorine from the molecule.

New products launched

Nitration, oxidation, and reduction are also strengths of Ems Dottikon, Dottikon, Switzerland. At the exposition, the company unveiled monosubstituted piperazines, substituted *o*-phenylenediamines, indoles, indazoles, and benzimidazoles as new products based on these. For example, the company makes 1-acetyl-, cyclohexylmethyl-, and ethylpiperazines free of disubstituted compounds. Also new are 4-chloro- and 5-methoxyindole, as well as indolecarboxylic acids and esters. By way of reassuring customers about attention to the environment, Ems Dottikon will start up a new waste incinerator this summer.

Cyclopropanes make up the core technologies at Hüls of Marl, Germany. Some of these compounds come from condensations of ethylene dihalides with malonate esters, which can be followed by hydrolysis and decarboxylation. The company's other cyclopropanations are proprietary. The new products from Hüls include 2-methyl-, 2,2-dimethyl-, and unsubstituted cyclopropanecarboxylic acids and esters,

Versatile intermediate is made by cyclic process



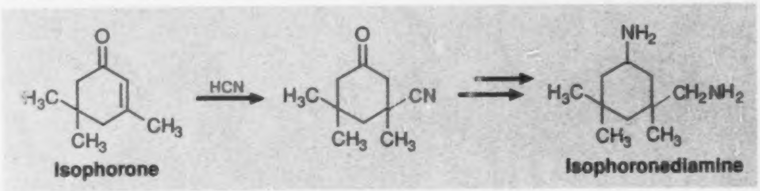
Source: Lonza

and carbonamides, carbonitriles, carboxaldehydes, carbinols, and carbinyl chlorides.

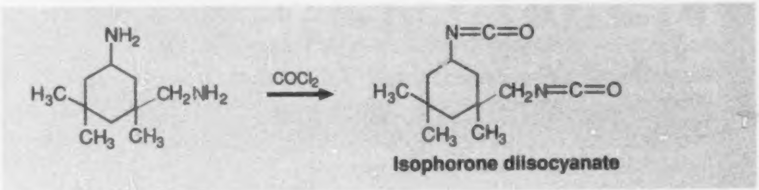
Sepracor of Marlborough, Mass., has prospered on enantioselective technologies licensed from academic chemists. In Manchester, the company showed off an enantioselective method of its own.

Sepracor has previously licensed the asymmetric dihydroxylation of olefins invented by organic chemistry professor K. Barry Sharpless of Scripps Research Institute, La Jolla, Calif., and the asymmetric epoxidation of olefins invented by organic chemistry professor Eric N. Jacobsen of Harvard University. Tradenamed ChiRedox-AR, the new technique uses a catalyst with a proprietary enantiomeric ligand to mediate reduction of carbonyl groups and olefins with diborane.

Hydrogen cyanide is a route to an epoxy resin hardener . . .



. . . or an ingredient of polyurethane coatings



The technique reduces alkyl phenyl ketones to enantiomeric carbinols, N-isopropylphenylglyoxaldimine to either enantiomer of 2-dimethylamino-1-phenylethanol, ethyl α-methylcinnamate to ethyl β-phenylbutyrates, and β-acetaminocinnamic acid to *N*-acetylphenylalanines. Sepracor is offering a half-dozen new enantiomeric intermediates based on the reduction.

Celgene Corp. of Warren, N.J., exhibited commercially viable direct enzymatic conversion of racemic nitriles to enantiomeric carboxylic acids by nitrilases without having to go through intermediate amides. Previously, workers had to use a nitrile hydratase and

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Conferences, expositions bring producers, buyers

In addition to this year's ChemSpec Europe, three annual conventions are held in the U.S. to bring together sellers and prospective buyers of fine chemicals. Chemical Specialities USA '94 will meet in Chicago, Oct. 18–20, for its fifth year. Also, the 10th Annual Informex Trade Show & Technical Symposium will be held in Nashville, Feb. 20–22, 1995. And although enantiomers of chiral compounds are only a subset of fine chemicals, Chiral USA '94, held earlier this month in Reston, Va., was the second U.S. meeting of a yearly symposium dealing with their production and marketing.

Informex is sponsored by the Synthetic Organic Chemical Manufacturers Association (SOCMA) and focuses on custom chemical production. Most exhibitors also have catalogs of standard intermediates, however. Next year's meeting features a technical session, for which the program is not yet fixed, and a two-day exposition. That meeting is expected to draw 200 exhibitor firms and 1,400 attendees. For information, contact SOCMA, 1330 Connecticut Ave., N.W., Washington, D.C. 20036; phone (202) 659-0060.

Both the Chiral USA and Chemical Specialities USA conferences are organized by Spring Innovations, Stockport, England. For information about either event, in North America contact Brandon Associates, P.O. Box 1244, Merrimack, N.H. 03054; phone (603) 424-2035. Chiral USA '95 will be held at the Boston Marriott Long Wharf, May 14–16, 1995.

Chemical Specialities USA '94, which includes two days of technical sessions and an exposition with more than 100 firms exhibiting, is organized by FMJ International Publications, Redhill, England.

In addition, ChemSpec Europe '95 will take place in Essen, Germany, June 20–22.

an amidase in sequence to get this overall transformation.

Celgene spokesmen see the method as a route to alkyl-, aryl-, amino-, halo-, and hydroxy acids. In particular, the company is hoping it will be a low-cost route to such "profen" (α-substituted propionic acid) analgesics as ibuprofen, flurbiprofen, and ketoprofen. The racemic propionitrile could be converted to the desired enantiomeric profen, and the unreacted nitrile racemized and the racemate sent back through the nitrilase step.

At its booth, NutraSweet introduced chiral auxiliary reagents based on its position in L-phenylalanine, a component of the company's synthetic sweetener, aspartame. Chiral auxiliaries are enantiomeric compounds attached covalently to substrate compounds during multistep syntheses. The auxiliaries induce asymmetry into the substrate molecules and are cleaved off when no longer needed.

The new auxiliary compounds are (*S*)-enantiomers of 4-benzyl-2-oxazolidinone and its *N*-acetyl derivative, and 2-methyl-4-phenyloxazoline. The company will market these compounds through its fine chemicals subsidiary, NSC Technologies, also located in Mt. Prospect, Ill. And because D-phenylalanine is available as well, NSC also expects to offer the (*R*)-enantiomers of these auxiliaries soon.

Chiroscience of Cambridge, England, was also in Manchester to offer additions to its own line of enantiomeric synthons (advanced intermediates with broad applications). The company, which recently changed its name from Chiros, is in the businesses of supplying enantiomeric intermediates, redeveloping existing racemic drugs in enantiomeric forms ("racemic switches"), and discovering its own new enantiomeric drugs.

The intermediates shown at ChemSpec include single isomers of Vince's lactam, *tert*-leucine, *endo*-5-norbornen-2-ol, 2-alkoxycyclohexanones, piperidine-2-carboxylic acid, *cis*-3-cyclopentene-1,2-diol, 3-butyn-2-ol, 3-buten-2-ol, and the *N*-*tert*-butoxycarbonyl-protected derivative of 3-(4-thiazolyl)alanine. Chiroscience sees Vince's lactam, which it also lists as "γ-lactam," as an opening to all-carbocyclic antiviral analogs of nucleosides. Peptides containing *tert*-leucine gain metabolic hydrolytic resistance. And the butenol and butynol are useful for making alkaloids, steroids, vitamins E and K, and hormonelike messenger substances called prostaglandins.

Business development managers for FMC Corp.'s Lithium Division, Gastonia, N.C., came to Manchester to offer what they call applications-based synthesis. By this they mean application of the company's expertise in organolithium chemistry to carry out certain reactions or sequences of reactions to special order. The product furnished to the customer may not be an organolithium but rather may be based on a precursor that is.

Chemetall of Frankfurt, Germany, introduced lithium diisopropylamide (LDA) and lithium bis(trimethylsilyl)-amide. These are potent bases used in organic syntheses, such as the production of enolates, which have the virtue of being nonnucleophilic. They are furnished as 10% solutions in hexane, and the LDA solution contains a proprietary stabilizer.

Managers from Callery Chemical Co., Pittsburgh, Pa., came to Manchester to announce the coming onstream of their new diborane plant in Evans City, Pa. The plant has a capacity of 60,000 lb per year of diborane, 110,000 lb per year of dimethylamine-borane complex, and 180,000 lb per year of pyridine-borane. Callery makes diborane beginning with

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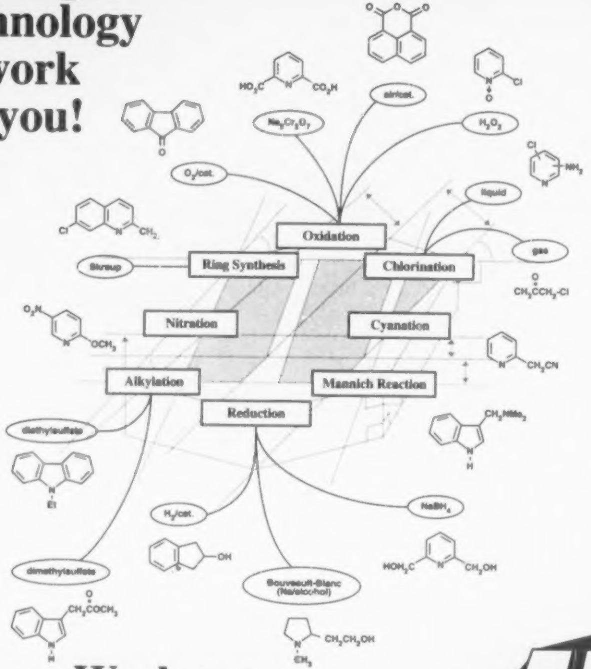

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conversion of borax to trimethyl borate. That ester reacts with sodium hydride to form sodium borohydride. And sodium borohydride yields diborane on treatment with boron trifluoride.

Eastman Chemical Co. mounted a display from the company's Liverpool, England, location. Eastman maintains a catalog of about 100 stock items but adds and deletes compounds every year. New this year are 10 substituted phenylmalondialdehydes, 10 heterocyclic arylmalondialdehydes, 10 aryl-β-keto esters, 20 methyl phenyl sulfones, and 10 indoles, including the 1-hydroxy-6-methanesulfonyl derivative.

Weyl of Mannheim, Germany, a subsidiary of Rütgerswerke, introduced fluorenylidene-4,4-diphenol, whose diglycidyl ether shows promise in epoxy resins. The fluorene nucleus renders such resins hydrophobic, which is valuable in tropical climates where epoxy adhesives, coatings, and potting compounds can degrade from humidity.

Environmental concerns

Environmental protection was the concern expressed in several presentations in Manchester. For example, heterogeneous catalysts were described that can be filtered away from reaction mixtures and reused, so they don't end up in a waste stream for treatment. And enzymes or cell cultures usually work without leaving a heavy-metal residue.

A literally prize-winning approach has been that of drug producer Hovione, headquartered in Lisbon, Portugal. Fiona Macleod, chief of process engineering at the company's plant in nearby Loures, described the measures that led the European Community, now called the European Union, to award the firm its Better Environment for Industry Prize for 1992.

The company produces about 60,000 kg of semisynthetic tetracycline antibiotics and 200 kg of corticosteroids per year. Important materials used include solvents acetone and methanol and triphenylphosphine-rhodium hydrogenation catalyst.

Hovione did not win the award by coming from behind. "The question of environmental protection has always been addressed at Hovione," Macleod says, "and Hovione's waste stream has always been subject to control and treatment. But most of our customers are in the U.S., so it was obvious that we had to exceed local legislation."

Association goes to bat for specialty chemical makers

The British Association for Chemical Specialities (BACS), organizer of the ChemSpec Europe symposia, is the advocate for British specialty chemical producers, representing them both to British and European Union legislative and regulatory bodies. BACS's 135 member firms are concerned mostly with such formulated specialty chemicals as industrial biocides, specialty surfactants, and water-borne polymers. Despite this variety, the most successful ChemSpec Europe symposia programs have focused increasingly on the fine chemicals segment of specialty chemicals.

For 10 years, Alan W. B. Cowan has been director of BACS. Cowan will step down as director this year but will stay on as secretary. BACS has selected consultant Richard J. Farn as the new director.

Farn says he will move BACS headquarters offices from Sutton, near London, to Manchester or a location close by. He explains that Manchester is the center of gravity of the British specialty chemicals industry.

By improving their processes, Hovione engineers were able to reduce solvent use 20 to 30%. Building a separate, \$5 million dedicated recovery and treatment plant further improved efficiency of solvent use so that purchase of new solvents was reduced by 85% overall. Macleod explains that the recovery-treatment plant was purposely built physically apart and functions administratively as a stand-alone entity so that engineers could run it independently and not just as an adjunct to production.

Solvent recovery became economically more favorable when the U.S. Food & Drug Administration accepted the company's specifications for recycled solvents. For example, the recovered acetone contains a small amount of water, but water is added to acetone before use in the processes anyway. And the methanol is slightly alkaline, but methanol is acidified before use in processes.

Rhodium is recovered as a concentrate and sent to Degussa for reclamation and a credit. Originally, managers

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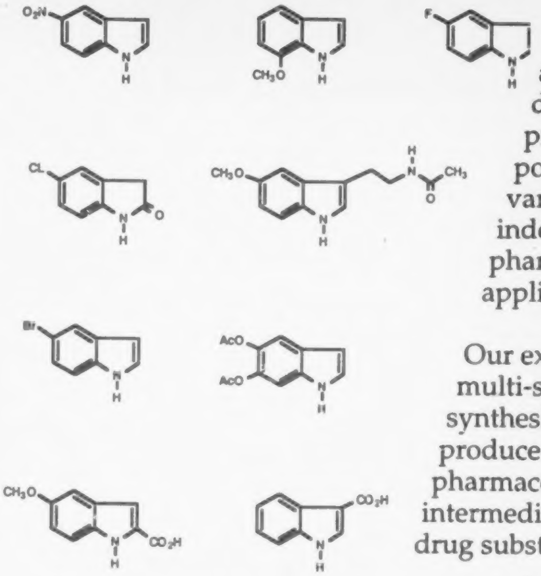

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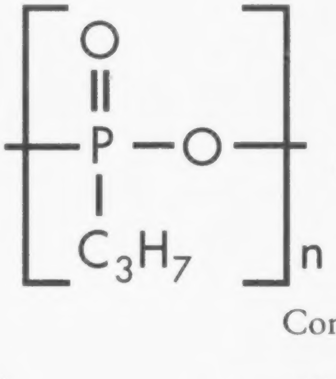

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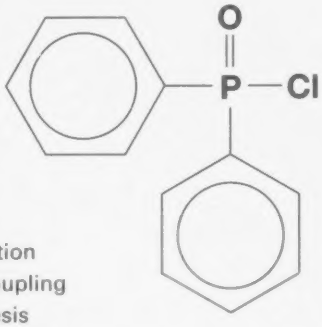

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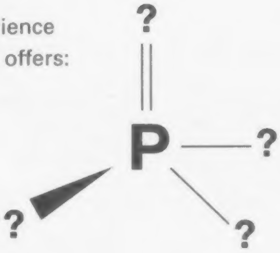

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at Hovione looked to then-high prices of rhodium to defray many expenses. But rhodium prices have since tumbled, and it is the economics of solvent recovery that make the whole operation viable.

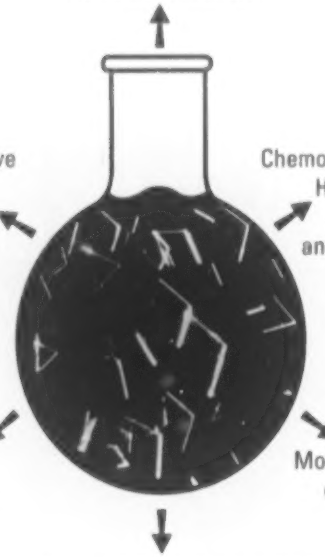
"Rich" solvent streams (high-solvent/low-water content) are targeted for distillation and recovery. "Lean" streams go for incineration, with cogeneration of steam. One aqueous stream from acetone recovery must pass through the incinerator because base-catalyzed condensation of acetone produces trace amounts of diacetone alcohol and mesityl oxide, which render the water "too smelly" for sending to the local sewage works.

Macleod describes the only loose end as triphenylphosphine, which ends up as the oxide. The company so far has been unsuccessful in selling the oxide and lacks the capability to recover triphenylphosphine. Macleod says that Hovione welcomes suggestions about what to do with the triphenylphosphine oxide.

As to use of heterogeneous catalysts to design environmentally acceptable processes, Brian Trenbirth, technical director of Contract Chemicals, Knowsley, England, described his firm's line of "supported reagents" at the Manchester meeting. Tradenamed Envirocats, these are proprietary preparations based on impregnation of clay or alumina with chemicals. They are used in catalytic amounts to mediate benzoylations, acetylations, alkylations, arenesulfonylations, and air oxidations.

Advantages of the catalyst intended to replace anhydrous aluminum chloride in benzoylations and acetylations are many. For example, it is used in 10% of the usual amount of aluminum chloride, can be filtered off afterward, often can be reused, is inert to water, does not leave residue in products, is not a chemical irritant, and does not cause scrambling of such groups as methyl. Nor does it cause disproportionations, in which products rearrange intermolecularly to give a mixture of polymethylated and unmethylated molecules.

The catalyst's insensitivity to water is demonstrated by reaction conditions for processes involving benzene. The user adds the catalyst to the benzene in the reactor and simply distills until the azeotrope has carried off all the water from the "wet" benzene. In those cases where



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the catalyst cannot be reused, Contract Chemicals will take it back, still damp with solvent, for regeneration.

Catalysts are available for benzoylation with benzoyl chloride; acylation with acid chlorides or anhydrides; benzylation with benzyl or benzal chloride; alkylation with alkyl halides, olefins, or formaldehyde (production of diarylmethanes); arenesulfonations with arenesulfonyl chlorides; and such air oxidations as that of *o*- or *p*-ethylaniline to aminoacetophenones.

Zeolites also serve as heterogeneous catalysts in making fine chemicals, according to Andreas Vogt of CU Chemie Uetikon, Lahr, Germany. Vogt, who is manager of product development, notes that these aluminosilicate catalysts make possible many useful transformations without the toxic or corrosive compounds often required.

For example, a titanium zeolite catalyzes formation of cyclohexanone oxime from cyclohexanone, ammonia, and hydrogen peroxide. Thus there is no need to use hydroxylamine. And a zeolite called Y catalyzes the Beckmann rearrangement of cyclohexanone oxime to caprolactam, the precursor of nylon 6, without need for strong mineral acids.

In another rearrangement, *m*-phenylenediamine is converted to a mixture of 2-amino-6-methyl- and 4-amino-2-methylpyridines. And a zeolite catalyzes the Fries rearrangement of phenyl acetate or benzoate to a mixture of *o*- and *p*-hydroxyacetophenones and -benzophenones, bypassing the problems of using anhydrous aluminum chloride as catalyst.

The titanium zeolite finds use in Italy to produce 10 million kg per year of catechol and hydroquinone from phenol and hydrogen peroxide, Vogt says. And the mordenite form of zeolite catalyzes nitration of benzene without use of sulfuric acid.

Process safety concerns

In addition to the environment, process safety is a constant concern in the fine chemicals industry. The fear is that a process may be inherently unstable, which means that at a certain temperature, a reaction may become autocatalytic and run away.

Process engineers have long known that they must add reactants to a vessel at a rate so that the temperature does not rise too much too fast. But slow rates of dosing large reactors lead to longer reaction times that hurt the economics of production and allow time for side reactions and product decomposition to occur.

As Jimmy B. Hunter of SynProTec, Manchester, England, points out, the volume of a reactor—the amount to be cooled—increases as a cubic function of the dimensions. But the surface area available to apply cooling increases only as the square. Hunter cites the case of a British company that divides batches of 2,4-dichlorophenol production among six reactors in order to add chlorine fast enough to keep batch times under 15 hours.

Hunter is commercial director at SynProTec, a chemical engineering consulting firm. The firm specializes in designing loop reactors to a client's order for chemical reactions. A loop reactor system continuously circulates the reaction mixture out of the reaction vessel through heaters, coolers, and mixers as needed to keep the reaction under control.

Loop reactors are well known. Indeed, at the Manchester exposition the chemical equipment firm Buss, of Pratteln, Switzerland, introduced self-contained, skid-mounted, 200-, 500-, and 1,000-L loop reactors especially

2

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Sepracor and Zeneca booths at ChemSpec Europe '94.

for medium-scale hydrogenations.

The Buss name in loop reactors is prestigious, as evidenced by custom producers of fine chemicals who list them by name in their capabilities brochures. Buss units are expensive, however. The new hydrogenation units introduced in Manchester cost $750,000 to buy and about as much to install. SynProTec specializes in designing loop reactor systems around off-the-shelf equipment to keep costs down. How well that approach will compete against Buss remains to be played out.

In a SynProTec system, one reactant is held in a tank and circulates out from the bottom, upward through a static mixer, through a heat exchanger for cooling, through another heat exchanger for heating, and finally back into the top of the tank. The second reactant is added to the first just as the stream leaves the tank and enters the static mixer. The reaction occurs in the mixer and heat exchanger. The one heat exchanger for heating is used only to heat the mixture to the needed temperature.

Hunter says the heat exchanger for cooling can be built to any size needed. Thus heat removal is not the bottleneck, and reactions can be controlled no matter how exothermic. High flow rates increase cooling efficiency, which means that the heat exchanger can be relatively small. The static mixer design favored by SynProTec gives high rates of mass transfer, Hunter says, so reactions of gases or immiscible liquids occur efficiently. Hunter claims that capital costs are low because the tanks, pumps, and heat exchangers are cheaper than jacketed reactors. And he says the concept can be retrofitted to an existing reactor. ☐

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Solid Sales Gains Finally Kick In For Major Chemical Companies

■ ***Chemical earnings also climb in first quarter as oil, diversified, and pharmaceutical firms post financial gains as well***

William J. Storck,
C&EN Northeast News Bureau

The U.S. chemical industry put in a solid performance in this year's first quarter and, coupled with even better finances the previous quarter, seems to be heading firmly out of the recession.

Although the year-to-year 22% earnings gain in first-quarter 1994 for 30 major chemical companies surveyed by C&EN is less than the 34% rise by these companies in fourth-quarter 1993, the overall results show a more fundamentally sound industry. Perhaps just as important as the healthy earnings gain is the 5% average increase in sales. After essentially three years of almost flat sales in the industry, the news is certainly welcome. And it indicates that, for the first quarter at least, earnings increases are coming from improved business as well as cost cutting.

The improving economy has bolstered downstream domestic markets for chemicals. Rising demand for housing, along with increased purchases of automobiles and other big-ticket durable goods, has led to increased demand for chemicals. As a result, chemical shipments are increasing, inventories are shrinking, and production is up.

According to data from the Commerce Department, the value of shipments of chemicals and allied products in the first quarter grew 3.6% from first-quarter 1993. And for the major subcategory of industrial chemicals, shipments, which for some time had been lackluster at best, rose 2.9%. Meanwhile, inventories of chemicals and allied products fell 2.5% and those of industrial chemicals decreased even more—5.6%.

Whether March, the final month in the quarter, was an aberration or the beginning of a trend remains to be seen, but shipments growth in that month increased strongly, 5.2% from March 1993 for overall chemicals and allied products and 4.4% for industrial chemicals. Although growth in other recent months has slightly exceeded this rate for chemicals and allied products, the increase for industrial chemicals is the highest in almost a year. During March, while inventories of the broader category fell just

Ground rules for C&EN earnings analysis

C&EN's quarterly report on financial performance of the U.S. chemical industry contains data from the 30 largest U.S. basic chemical companies and from 25 oil and diversified companies, each with more than $200 million in annual chemical sales, plus 10 pharmaceutical companies.

To be included in the table of basic chemical producers, a company must have at least 50% of its sales in chemicals. That is why DuPont, for example, is included in the table of diversified manufacturers.

In referring to chemical sales, C&EN means those chemicals whose molecular composition has been changed in the course of manufacture. Hence, chemical sales include those of traditional categories of basic petrochemicals and inorganics, organic intermediates and inorganic compounds, polymers such as plastics and fibers, and agricultural chemicals and specialty derivatives.

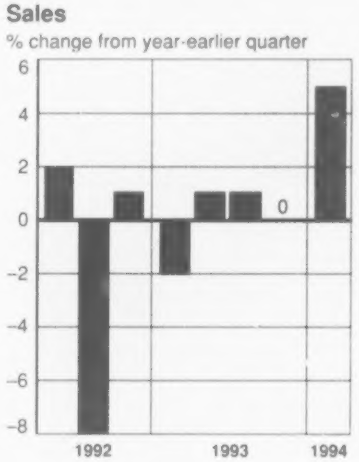
Chemical industry leaders for first-quarter 1994

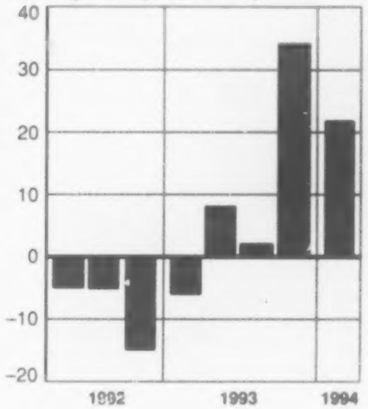
Sales				Earnings[a]			Profitability		
Rank 1994		$ Millions	Rank 1993		$ Millions	Rank 1993		Earnings as % of sales	Rank 1993
1	**Dow Chemical**	$4,541.0	1	**Monsanto**	$194.0	1	**International Flavors**	18.2%	1
2	**Monsanto**	2,001.0	2	**Dow Chemical**	171.0	2	**Great Lakes Chemical**	14.9	2
3	**Union Carbide**	1,126.0	3	**Air Products**	73.1	3	**Loctite**	11.4	3
4	**W. R. Grace**	1,076.8	4	**Morton International**	71.3	8	**Lubrizol**	10.9	6
5	**Eastman Chemical**	983.0	—	**Union Carbide**	71.0	10	**Betz Laboratories**	10.7	4
6	**Air Products**	858.6	5	**Rohm and Haas**	67.0	5	**Nalco Chemical**	10.1	5
7	**Rohm and Haas**	856.0	6	**Great Lakes Chemical**	66.9	4	**Monsanto**	9.7	11
8	**Morton International**	808.3	9	**International Flavors**	58.9	6	**Crompton & Knowles**	9.5	7
9	**Arco Chemical**	757.0	7	**Eastman Chemical**	56.0	—	**Morton International**	8.8	10
10	**Hercules**	680.0	8	**Hercules**	54.8	9	**Air Products**	8.5	8

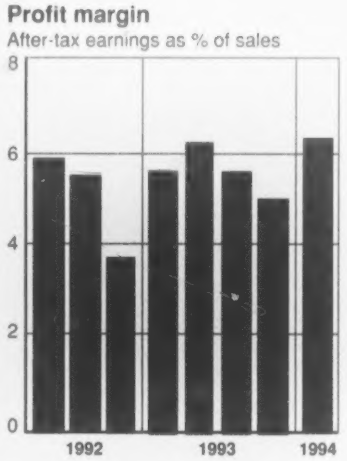
Note: Based on 30 chemical companies listed on page 32. a After taxes.

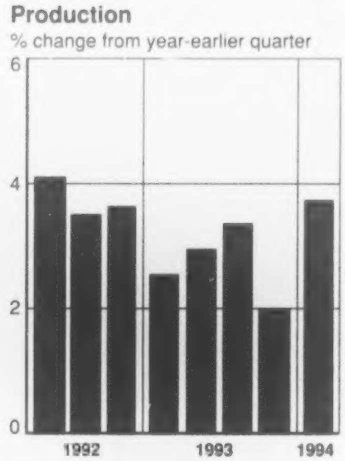
Chemical industry 1994 first-quarter results

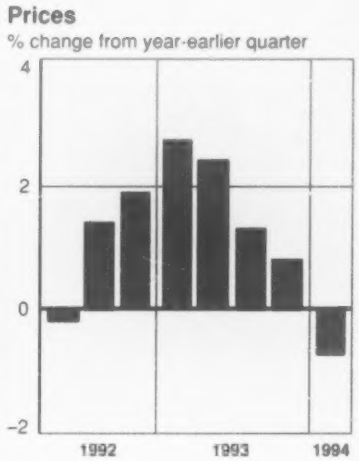
- **Sales increased 5%**
- **Earnings rose 22%**
- **Profitability was 6.4%**
- **Production rose 3.7%**
- **Prices fell almost 1%**











Note: All sales, earnings, and profit-margin data are based on the 30 chemical companies listed on page 32

2.5%, stocks of industrial chemicals dropped 6.4%.

Production also is increasing to keep pace with the rising demand. For the first quarter, output from chemical plants rose 3.7% on an annual basis. But prices still lag with a first-quarter decline of almost 1.0%.

The result of these factors was that earnings for the 30 chemical companies in first quarter 1994 rose 22% from last year's first quarter to a total $1.27 billion on a 5% sales increase to $19.9 billion. Thus, the aggregate profit margin for the group rose to 6.4% from last year's 5.5%.

The list of the 30 major chemical companies (firms that derive 50% or more of their sales from chemicals) has changed from earlier years because many companies have gone through significant realignments in the past 12 months. Cytec, the chemical spin-off from American Cyanamid, has replaced Cyanamid on the list. Geon, the polyvinyl chloride manufacturer spun off from BF Goodrich, has replaced its former parent. Like Cyanamid, Goodrich has seen its chemical sales shrink below 50% as it concentrates on other business areas. Goodrich has been increasing its aerospace operations; Cyanamid is looking more to drugs for growth.

In addition, Albemarle, the spin-off from Ethyl Corp., has been added to the list, although a much smaller Ethyl remains because now its major business, lubricant and fuel additives, is chemicals. And Eastman Chemical, spun off from Eastman Kodak, has been added to the list. Another change in the list is the shift of Imcera, now called Mallinckrodt Group, to the diversified companies list, because its chemical sales dropped below 50% of its total sales.

The companies that have been added undoubtedly weight the sample more toward chemicals than it has been in years. All of them are essentially 100% chemical companies. Since they replace companies that had large nonchemical

Sales rose for 24 major chemical companies, earnings were up for 22

	FIRST-QUARTER 1994						12-MONTH RUNNING DATA			
	Sales	Earnings[a]	Change from 1993		Profit margin[b]		Change from 1993		Profit margin[b]	
	($ millions)		Sales	Earnings	1994	1993	Sales	Earnings	1994	1993
Air Products	$ 858.6	$ 73.1	3%	–3%	8.5%	9.0%	2%	0%	8.3%	8.4%
Albemarle	241.8	9.8	12	84	4.0	2.5	na	na	na	na
Arco Chemical	757.0	45.0	–1	–13	5.9	6.8	2	–13	6.8	8.0
Betz Laboratories	172.9	18.5	3	–3	10.7	11.4	–1	–14	10.2	11.6
Cabot	434.9	22.3	7	59	5.1	3.4	6	44	4.3	3.2
Crompton & Knowles	133.6	12.8	0	4	9.5	9.2	4	15	9.4	8.5
Cytec	258.1	8.2	10	90	3.2	1.8	na	na	na	na
Dow Chemical	4,541.0	171.0	4	35	3.8	2.9	–2	19	3.5	2.9
Eastman Chemical	983.0	56.0	4	–5	5.7	6.3	3	–8	6.9	7.8
Ethyl	234.0	14.0	–8	–33	6.0	8.3	na	na	na	na
First Mississippi	129.6	4.9	25	nm	3.7	def	6	240	2.2	0.7
H. B. Fuller	242.5	4.0	6	–15	1.7	2.1	5	–15	2.9	3.6
Geon	261.3	7.0	16	nm	2.7	def	11	nm	1.9	def
Georgia Gulf	192.9	12.7	6	26	6.6	5.6	1	6	5.9	5.6
W. R. Grace	1,076.8	38.2	9	21	3.5	3.2	–14	12	5.4	4.1
Great Lakes Chemical	448.7	66.9	4	4	14.9	14.9	15	13	15.1	15.4
Hercules	680.0	54.8	1	22	8.1	6.7	0	31	7.9	6.0
IMC Fertilizer	410.5	5.4	84	nm	1.3	def	37	nm	def	2.7
International Flavors	323.5	58.9	5	5	18.2	18.2	4	5	17.1	17.0
Loctite	159.9	18.3	7	–7	11.4	13.2	2	–18	10.7	13.3
Lubrizol	397.8	43.3	9	22	10.9	9.7	4	10	7.9	7.4
Monsanto	2,001.0	194.0	3	38	9.7	7.3	2	61	6.7	4.3
Morton International	808.3	71.3	25	48	8.8	7.4	21	35	7.7	6.9
Nalco Chemical	336.2	33.8	–1	–4	10.1	10.4	0	3	10.9	10.6
Olin	604.9	15.3	2	31	2.5	2.0	4	–1	1.8	1.9
Petrolite	91.8	5.4	15	12	5.9	6.0	14	28	5.8	5.2
Praxair	611.0	42.0	3	27	6.9	5.6	–4	24	6.4	5.0
Rohm and Haas	856.0	67.0	4	16	7.8	7.0	4	–9	5.8	6.0
Union Carbide	1,126.0	71.0	–6	69	6.3	3.5	–6	88	4.4	2.2
Witco	553.4	22.0	0	17	4.0	3.4	17	38	4.2	3.6
TOTAL	**$19,927.0**	**$1,267.0**	**5%**	**22%**	**6.4%**	**5.5%**	**1%**	**15%**	**5.8%**	**5.2%**

[a] After-tax earnings from continuing operations, excluding significant nonrecurring and extraordinary items. [b] After-tax earnings as a percentage of sales. **na** = not available. **nm** = not meaningful. **def** = deficit.

operations, chemicals loom larger in the final results of the entire list

Business was better in the first quarter for most of the 30 companies. Sales were up for 24 of them, and two had the same sales as last year. Additionally, 22 of the 30 companies reported earnings gains, with three—First Mississippi, Geon, and IMC Fertilizer—having posted losses in the first quarter of 1993. Of the 22 companies that did show higher earnings, 16 had double-digit increases—13 of them were greater than 20%.

The largest of these gains was at newly formed Cytec, where earnings improved 90% from what the business units had posted for first-quarter 1993 to $8.2 million on a 10% sales gain to $258 million. Darryl D. Fry, chairman, president, and chief executive officer of the company, says: "Increased sales were reported in substantially all of Cytec's businesses. The strongest gains were in our specialty chemicals businesses due primarily to a strong North American economy, in spite of continued pressure on prices. International sales of specialty chemicals also improved in Europe and Latin America. Our improvement in earnings resulted from increased sales, our continuing emphasis on reducing costs, and higher equity earnings from affiliated companies."

Albemarle, also new, was second highest, with an 84% earnings gain to $9.8 million on a 12% sales increase to $242 million. Floyd D. Gottwald Jr., chairman and CEO, notes: "Our olefins and derivatives business showed a significant improvement in operating results from the prior-year period, especially in poly α-olefins and linear α-olefins. Other favorable areas were flame retardants, polysilicon, and a variety of chemical intermediates. Our first-quarter results are encouraging as we move forward as a new company."

Monsanto posted the largest dollar increase in earnings—$53 million to a total of $194 million. According to chairman and CEO Richard J. Mahoney, "The renewed momentum we had anticipated for our businesses is here. We will continue to fully develop our core products, drive our research investments to commercial success, and find innovative ways to add value for our customers, all the while keeping an unrelenting pressure on reducing costs."

At Dow Chemical, which also showed a hefty dollar rise of $44 million to a total of $171 million in earnings in the quarter, chairman and CEO Frank Popoff says, "We're very encouraged by the improvement in our operating income, which reflects enhanced productivity, continued economic growth in North America, and the beginning of an upturn in Europe."

The earnings growth was not limited to the chemical companies. A group of 12 oil companies that are major chemical producers reported total earnings up a slight 2% to $2.97 billion on a 5% sales decline to almost $70.0 billion. The aggregate profit margin for the group rose to 4.2% from 4.0%.

Drug companies, of which C&EN surveyed 10, showed slightly better performance, with earnings rising 5% to a total $3.49 billion. Sales rose a much greater 11%, however, to $20.1 billion. This drove the group's profit margin down to 17.4% from 18.4%.

The diversified group of 13 companies that make chemicals showed the biggest gains, with earnings rising an average of 28% to $1.51 billion on just a 3% increase in sales to almost $24.2 billion. Profitability increased to 6.2% from 5.0%.

At DuPont, still the largest U.S. chemical producer but which must be classified as a diversified company because of the huge share of revenues it derives from oil and other nonchemical businesses, earnings increased 39% to $642 million on a slight 1% sales rise to $9.19 billion. Chairman and CEO Edgar S. Woolard Jr. says: "Our significant reduction in costs is having the desired effect on our earnings, but it's also important to note that, compared to last year, we are seeing increased demand in key markets for a number of our businesses, including automotive products, engineering polymers, nylon, Lycra spandex, and nonwovens. Not only is demand generally improved in the U.S., but market conditions are better in Europe and Asia, where our chemicals and specialties sales are up 15% and 6%, respectively."

Diversified companies posted strongest earnings gain

	FIRST-QUARTER 1994					
	Sales	Earnings[a]	Change from 1993		Profit margin[b]	
	($ millions)		Sales	Earnings	1994	1993
OIL AND GAS COMPANIES						
Amoco	$ 2,322.0	$ 398.0	–9%	74%	17.1%	8.9%
Ashland	2,206.6	32.9	–8	110	1.5	0.7
Chevron	8,264.0	388.0	–9	–23	4.7	5.5
Exxon	25,964.0	1,160.0	–5	–2	4.5	4.3
Fina	777.5	25.0	–9	30,041	3.2	0
Kerr-McGee	800.9	23.6	2	–3	2.9	3.1
Mobil	15,118.0	535.0	0	9	3.5	3.3
Occidental Petroleum	2,106.0	–34.0	–3	nm	def	3.6
Phillips Petroleum	2,924.0	127.0	–5	108	4.3	2.0
Shell Oil	5,515.0	219.0	–2	15	4.0	3.4
Sun Co.	2,067.0	34.0	–10	–3	1.6	1.5
Unocal	1,916.0	62.0	–17	–37	3.2	4.2
TOTAL	**$69,981.0**	**$2,970.5**	**–5%**	**2%**	**4.2%**	**4.0%**
DIVERSIFIED MANUFACTURERS						
AlliedSignal	$ 2,986.0	$ 169.0	3%	16%	5.7%	5.0%
DuPont	9,190.0	642.0	1	39	7.0	5.1
Engelhard	557.7	22.8	14	43	4.1	3.2
Ferro Corp.	283.3	11.3	10	–14	4.0	5.1
FMC	908.3	46.1	1	2	5.1	5.0
Freeport-McMoRan	449.6	23.4	49	nm	5.2	def
BF Goodrich	502.4	4.9	33	nm	1.0	def
3M	3,632.0	306.0	3	–7	8.4	9.4
Mallinckrodt Group	486.7	42.9	11	41	8.8	6.9
NL Industries	174.2	–6.4	1	nm	def	def
PPG Industries	1,476.9	121.9	2	30	8.3	6.5
Tenneco	3,286.0	129.0	1	74	3.9	2.3
Vulcan Materials	216.9	–5.2	1	nm	def	def
TOTAL	**$24,150.0**	**$1,507.6**	**3%**	**28%**	**6.2%**	**5.0%**
PHARMACEUTICAL COMPANIES						
Abbott Laboratories	$ 2,215.2	$ 366.2	8%	6%	16.5%	16.9%
American Home Products	2,144.0	415.0	2	3	19.4	19.0
Baxter International	2,193.0	131.0	7	8	6.0	5.9
Bristol-Myers Squibb	2,833.9	581.0	3	1	20.5	20.9
Eli Lilly	1,637.0	368.7	5	–1	22.5	23.9
Merck	3,514.3	675.2	48	10	19.2	25.8
Pfizer	1,982.9	370.7	6	6	18.7	18.7
Schering-Plough	1,161.6	253.2	7	13	21.8	20.5
Upjohn	906.0	135.0	–1	–2	14.9	15.1
Warner Lambert	1,472.9	190.4	11	5	12.9	13.6
TOTAL	**$20,060.9**	**$3,486.4**	**11%**	**5%**	**17.4%**	**18.4%**

a After-tax earnings from continuing operations, excluding significant nonrecurring and extraordinary items. **b** After-tax earnings as a percentage of sales. **nm** = not meaningful. **def** = deficit.

Although earnings were generally up across the board, chemical executives are not so sanguine as to predict a straight and smooth recovery. On the outlook for his company, but perhaps just as applicable to the U.S. chemical industry, J. Lawrence Wilson, chairman and CEO at Rohm and Haas, says: "We expect volume growth to remain strong as 1994 progresses. We will continue to face an unfavorable currency situation in Europe, but we expect to see additional relief in external economic conditions as the year progresses. And, while selling prices were slightly below last year's level, we did begin to detect a more favorable environment for price increases during the quarter. We will pursue price increases wherever we can. In short, we expect to see continued favorable earnings comparisons as the year unfolds." ☐

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CHEMICAL & ENGINEERING NEWS
C&EN
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EPA DRAFT DOCUMENT CONCLUDES THAT DIOXINS ARE HEALTH RISK PAGE 13

PLASTICS IN CONSTRUCTION

New building products take growing share at expense of traditional materials
Page 20

CHEMICAL & ENGINEERING NEWS

C&EN

MAY 30, 1994

NEWS OF THE WEEK

- Scripps scientists have carried their work on peptide nanotubes further, forming artificial ion channels in cells that may offer way to insert drugs into cells. Page 4
- Genzyme has received FDA okay to market recombinant form of an enzyme, the first recombinant "housekeeping" enzyme, to treat Gaucher's disease. Page 5
- Fighting hard to ward off Administration plans to temporarily freeze indirect research cost payments, university representatives propose cutting research budgets instead—infuriating research scientist association. Page 5
- Senate committee contends U.S. troops in Gulf War were exposed to harmful levels of chemical and, possibly, biological warfare agents, contributing to recently reported health problems. Page 6
- Several environmental activist groups have sued EPA in an effort to force it to disclose the inert chemicals used in pesticide formulations, charging that these chemicals are neither safe nor inactive. Page 6
- Chemical firms support Clinton's decision to keep China's "most favored nation" trade status, argue that any sanctions would be counterproductive. Page 7

COVER: Workman applies Eiger Building Products' roofing sheets that look like cedar shake shingles but are made of General Electric's polyphenylene oxide resins

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BUSINESS

Flavors and fragrances business has grown steadily, is more like the drug business than the chemical industry in innovation, R&D spending, and merger activity, says head of Haarmann & Reimer, flavors and fragrances arm of Germany's Bayer. Page 10

GOVERNMENT

Part of EPA's risk assessment study of dioxins and similar compounds suggests dioxins, furans, and polychlorinated biphenyls have potential for harming humans and the environment. Page 13

Group assessing National Institute of General Medical Sciences' predoctoral training programs finds programs are doing a superb job, suggests need for more data to really judge success. Page 14

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New technique to immobilize enzymes in polymeric microcapsule arrays that look like bristles on a brush may find application in bioreactors and biosensors. Page 17

STN International, the on-line science and engineering database begun by ACS's Chemical Abstracts Service and FIZ-Chemie in Germany, celebrates 10th year of service. Page 18

EDUCATION

Five high school students from Atlanta win fourth annual National Science Bowl, edging out a team from Houston; winners will research endangered wildlife in Switzerland. Page 19

MEETINGS

13th International Conference on Chemical Education, to be held in Puerto Rico in August, features symposia and workshops of interest to precollege and college chemistry teachers. Page 49

PRODUCT REPORT

Use of plastics in construction and building has been increasing moderately as manufacturers strive to develop products that can compete—in cost and performance—with traditional materials. Page 20

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Editor: Michael Heylin (202) 872-4501
Managing Editor: Madeleine Jacobs
Assistant Managing Editors: James H. Krieger, Janice R. Long, Rebecca L. Rawls, Donald J. Soisson, William J. Storck
Staff Editor: Ernest L. Carpenter
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News Bureaus: Northeast: (908) 906-8300 Ann M. Thayer (Head), Elisabeth Kirschner (Assistant Editor), Rachel Eskenazi (Administrative Assistant). Houston: (713) 558-2912 Susan J. Ainsworth (Head). Washington: (202) 872-4495 David J. Hanson (Head). West Coast: (510) 653-3630 Rudy M. Baum (Head), (206) 517-5034 Deborah L. Illman (Associate Editor)
Foreign Bureau: London: (01) 4481 870-6884 Patricia L. Layman (Senior Editor)
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LETTERS

Questions about ISO registration

I compliment Ann Thayer for her comprehensive article on ISO 9000 registration (C&EN, April 25, page 10). The article points out aspects of this currently popular rush to registration that I find troublesome.

For example, on page 10, Thayer states, "ISO 9000 is not a product certification standard; registration in no way measures or recognizes the quality—good or bad—of a company's final product." On page 17, she writes, "Companies that use 9000 registration as a trophy or a blue ribbon are met with suspicion, if not derision, by quality managers. And customers unfamiliar with the details of ISO 9000 registration may be too naive to know better."

Yet in the very same issue of C&EN, there are three full-page ads from chemical companies that prominently proclaim ISO 9002 registration and imply they have superior quality products as a result. Let us all not be naive about this. Marketing departments are clearly promoting ISO registration to portray their products as somehow being of better quality than those of competitors who are not registered. The clear inference is that quality products are only achieved if companies belong to the ISO fraternity.

I also have a great concern about what this mad rush to ISO registration means to the future of small entrepreneurial companies. It is difficult enough for many entrepreneurs to break away from the security of a large company. Now they must also face the prospect of being locked out of markets unless they submit to the bureaucracy and cost of ISO registration and the accompanying third-party auditing of their operations. To many prospective entrepreneurs, this may be the deciding factor that keeps them from venturing forth.

Ironically, as a result of novel designs and fabrication techniques, quality has been one product feature on which small companies can often compete quite successfully with companies of much larger size. I believe that all companies, large and small, should have as a prime objective the continuous improvement of the quality of their products or services. However, I also believe in the contingency theory of organizations that states that what is right for one business is not necessarily right for another.

What of the companies that have achieved product quality on their own? Are they to be required to join the ISO fraternity just to stay in business? Will end customers really be better off without fresh new ideas and products that are traditionally spawned by entrepreneurs and small companies? What ever happened to the free-enterprise system whereby companies that made poor quality products simply did not survive in business? Is ISO registration being misused by some companies to project an image of perceived quality when real quality does not exist because of poor product design?

For many small companies, I wonder whether quality might better be maintained by instilling in their employees a sense of personal pride and ownership in the products they produce. To this end, funds that might otherwise be spent for outside registrars and auditors could better be directed to enhanced employee benefits and equity sharing in the success of the company.

Paul L. Patterson
Walnut Creek, Calif.

Respect for interviewees

As the spouse of a Ph.D. chemist who is currently seeking employment, I am writing to make your professional community aware of the deplorable treatment of interviewees for academic and industrial positions in chemistry. My husband has been invited on interviews by a variety of institutions and agencies, has gone through the usual process of presenting his research and speaking with faculty and staff, and then has left the interview process never to be contacted again. In some cases, he has received form letters three or four months later informing him that the position was canceled or filled by another individual, and thanking him for his time. I will not belabor my husband's impressive credentials and publication record; such disrespect is inexcusable toward any job applicant, irrespective of his or her qualifications. Nor is my husband's experience unique; in fact, his peers at three different research institutions confirm the universality of this practice.

Let me contrast this with my experience of the interview process for psychologists. In any institution or agency I have worked with, staff has been acutely aware of the

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vironmental Law Center, also of Eugene, a public interest law firm.

The dispute centers on chemicals used in pesticide products that are not the active ingredients. These so-called inerts often compose the bulk of a product, and NCAMP says that there are more than 2,300 substances used as inerts. Because these compounds are essential to the product formulation, chemical manufacturers often claim inerts are confidential business information.

NCAP and NCAMP complain, though, that these chemicals may be neither safe nor inactive. In their lawsuit, the groups list several compounds used as inerts, and thus not listed on product labels, that are actually canceled or registered pesticides. These compounds include acetone, dibutyl phthalate, *m*-cresol, and naphthalene. Some inerts are also regulated as hazardous chemicals under the Resource Conservation & Recovery Act, NCAP says.

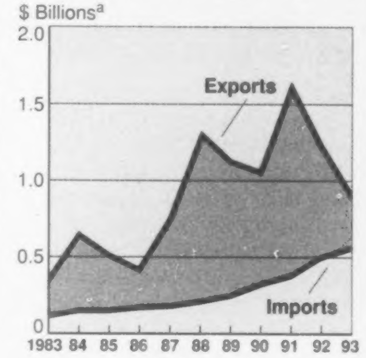
The citizen groups claim that because these compounds can be harmful, EPA has an obligation to tell the public when they are present in a product. To further complicate matters, NCAMP says companies sometimes will release the inert information to outside groups on request, even while EPA withholds the data.

For its part, EPA says it is following the Federal Insecticide, Fungicide & Rodenticide Act (FIFRA) by not releasing inert data, but it can if the compounds seem to present health risks. EPA has no official comment on the lawsuit at this time, according to a spokesman. He adds that EPA has taken action against some inerts in the past when health problems arose, but admits that the agency does not have health effects data on all the possible inert ingredients.

The National Agricultural Chemicals Association, which represents pesticide makers in Washington, D.C., says its member companies are telling EPA what is in each product as required by FIFRA. Also, manufacturers are making this information available to state and local poison control centers for emergency treatment if necessary.

David Hanson

U.S. chemical trade with China has falling surplus



a For chemicals and related products.
Source: U.S. Department of Commerce

U.S. chemical firms back China trade benefits

U.S. chemical companies will welcome President Bill Clinton's decision last week to seek renewal of China's "most favored nation" (MFN) trade status.

Chemical firms expressed strong opposition to U.S. imposition of trade sanctions in response to China's human rights and other policies. Such sanctions, the firms argued, would be counterproductive: They would harm U.S.-China trade and provoke Chinese countermeasures that could damage growing chemical trade and investment. Moreover, the firms believe, U.S. sanctions would not persuade China to pursue values and policies the U.S. seeks.

A report by the Congressional Research Service (CRS) notes that withdrawal of MFN status would raise tariffs on many imports from China to prohibitive rates. Chinese retaliation "would not likely have a significant *overall* effect on the U.S. economy" but could hurt "vulnerable" U.S. exports of materials readily obtainable from other suppliers, including chemicals and allied products (such as fertilizers) and plastics.

The U.S. has a highly favorable chemical trade balance with China, with exports exceeding imports by $700 million to $1.3 billion during 1988–92. Last year, the surplus plummeted to $263 million.

For example, China bought $293 million worth of U.S. fertilizers in 1993, 16% of all U.S. fertilizer exports. Of the top 15 U.S. exports to China, fertilizers would be hit the hardest by cuts in Chinese purchases, CRS finds.

China imported $386 million worth of U.S. industrial chemicals in 1992, out of $2.5 billion in total imports. U.S. exports are projected at $432 million for 1993, with 12% growth per year from 1993 to 1995. "U.S. firms face stiff competition" from Chinese and foreign producers, CRS says.

Fertilizers top U.S. chemical exports to China

$ Millions	1993 Exports	1993 Imports
Organic chemicals	$204	$127
Inorganic chemicals	25	134
Dyeing & coloring materials	29	39
Pharmaceuticals	27	126
Oils, perfumes & cleansing products	21	35
Fertilizers	293	0
Primary plastics	168	16
Nonprimary plastics	22	6
Other chemical materials & products	51	92
TOTAL	$839	$576

Source: U.S. Department of Commerce

U.S. exports of plastic materials and resins to China hit $464 million in 1992, out of $4.8 billion in total imports. U.S. sales of $361 million are projected for 1993, falling 12% per year from 1993 to 1995 under steep competition.

The Fertilizer Institute, representing that industry, has been monitoring the MFN issue closely. The institute wrote a key member of Congress that "Revocation of MFN status will only harm U.S. interests without helping the people of China. China will easily find other sources of needed materials and feel no foreign policy pressure." Meanwhile, the Society of the Plastics Industry last week adopted a statement backing continued MFN status for China.

Chemical companies that belong to the Chemical Manufacturers Association have sought MFN renewal for China—without conditions attached—through umbrella groups like the Business Coalition for U.S.-China Trade. A letter to President Clinton from the coalition includes a number of chemical firms among its hundreds of signatories.

The letter stresses that MFN can be a catalyst for human rights—as economic development, and foreign trade and investment, spur evolution toward a more open and democratic society. "In China, American trade and investment advance American ideals," it says. "Over the last decade, the driving force for economic and political reform has been the emergence of a dynamic and entrepreneurial private sector."

Richard Seltzer

Flavors And Fragrances Business Marked By Growth, Mergers

■ ***Haarmann & Reimer chief says industry is like pharmaceuticals in innovation, R&D spending, consolidation***

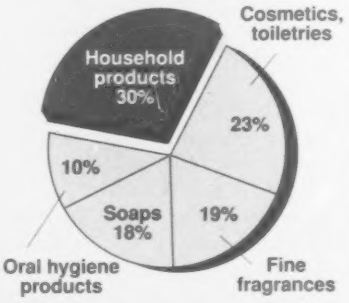
Patricia L. Layman, C&EN London

The rest of the chemical industry may have been through some down times in recent years, but the flavors and fragrances industry has enjoyed steady growth. Producers are finding increases not only in their home markets; indeed, they are scrambling to cater to the double-digit growth now occurring in many Asian countries.

As Hans Hartmann, president and chief executive of Haarmann & Reimer, the flavors and fragrances arm of German chemicals giant Bayer, notes in a C&EN interview: "The industry has continued to grow about equally with consumer goods growth. Even when other industries were down, ours showed some growth," certainly better than the average of the chemical industry.

Moreover, even though growth has slowed somewhat, it is still roughly 3 to 5% on an annualized basis for perfumes and aroma chemicals, and slightly higher for food flavors. That continues the solid performance the industry has shown for decades.

Household products are biggest use of fragrances



1993 fragrances sales = $4 billion

Now worth nearly $9 billion worldwide, of which $4 billion is fragrances and $5 billion flavors, the industry has long been seen as attractive and profitable. Profitable enough, for example, to have caused otherwise sensible chemical and consumer-goods companies to snap up flavors and fragrances producers in the 1970s—moves that nearly all turned sour.

The result has been divestitures of flavors and fragrances operations, usually to companies already in the business. Additionally, mergers have continued, as producers work to become large enough to handle international business.

The only publicly traded flavors and fragrances company is International Flavors & Fragrances, which probably accounts for about 13% of total industry sales. In 1993—"another year of solid growth," as the company puts it—pretax profits climbed 15% from those of 1992 to $324 million. Sales were up 6% to $1.19 billion, of which fragrances were $699 million and flavors $489 million.

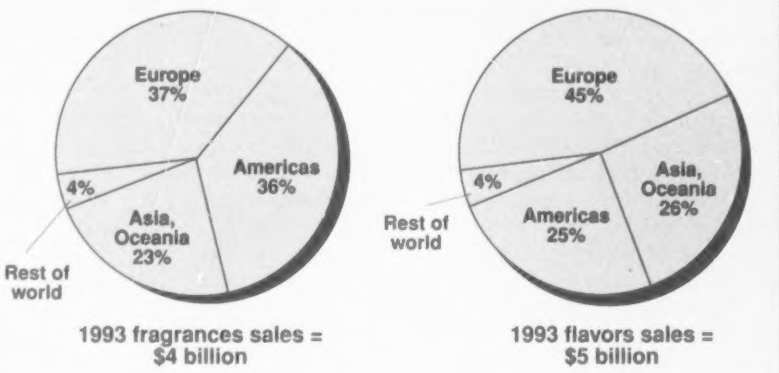
The other major companies in the business are either subsidiaries of large multinationals—Givaudan, of Roche Group, Switzerland; Quest, of Anglo-Dutch Unilever; Haarmann & Reimer, of Bayer—or privately held, as is Swiss-based Firmenich. These five—International Flavors, Givaudan, Quest, Firmenich, and Haarmann & Reimer—account for nearly half of flavors and fragrances sales.

Several other companies are much smaller than these five producers but are still significant players in the business. These are Bush Boake Allen, U.S.; Takasago, Japan; Dragoco, Germany; Florasynth, U.S.; Sanofi, France; and Tastemaker, a joint venture of Hercules' PFW Flavors and Mallinckrodt's Fries & Fries.

And most of them would argue that one of the reasons earlier purchases by big chemical companies went awry is that "We are not chemical companies," as Hartmann puts it, but more akin to drug companies in the way they approach innovation. His own company, for example, now spends about 7% of total sales on research and development—the same proportion as a pharmaceutical company would spend (a chemical company would spend 3 to 4%). For Haarmann & Reimer, that means last year's R&D spending was roughly $60 million—7% of 1993 sales of $856 million. Sales in 1993 were double those of five years ago.

Hartmann: not chemical companies

The high level of R&D spending—in part to cope with increasingly stringent environmental requirements, flavor and fragrance safety testing, and the need to serve international customers—is driving mergers in the industry, Hartmann says. The mergers have tended to be between large- and medium-sized companies, as management faces the daunting prospects of finding the resources to follow those trends or to expand operations.



Fragrances, flavors use pattern differs geographically

Nonetheless, a sizable number of small- to medium-sized companies remain in the flavors and fragrances business, he adds. But their options are becoming limited: Either they are local suppliers, or they "have to play a world game."

Hartmann is well poised to do this. Despite his assertion that "we are not chemical companies," Hartmann's background is in Bayer's chemical operations. He joined Haarmann & Reimer's board in 1987 and took over last May as chief executive, succeeding Claus Skopalik, who had been in the company's top management for 25 years.

However, pitched from the chemical industry into a world dominated by sensuality and artistic talent, Hartmann had a saving grace—he came from Bayer's dyes and colors business. When he was visiting the various Haarmann & Reimer sites to get to know the business, one perfumer asked him his background. Dyes and colors? "Ahh, colors—then you will know about beauty," Hartmann was told.

Whether these particular talents will serve him well in the global marketplace is not yet known. One "must-enter" marketplace, Hartmann says, is Asia, with its heady, double-digit growth rates. That, he emphasizes, includes China. "It is a big race: Who will be there first?" he asks.

"In Asia now, multinational consumer-goods companies are investing heavily in China—from soft drinks to detergent powders, noodle soups to cosmetics. These are not only Western multinationals, but Japanese, Taiwanese, Indonesian, and so on. They are our customers in their own countries, and we are asked to move with them," he points out.

"Only major companies can [make] this kind of investment—another reason why more and more companies in our industry are going through mergers. Our customers are becoming more global. They don't need dozens of suppliers."

In January, Haarmann & Reimer opened a new Singapore plant to expand sales operations it already had there. The new Singapore complex is dedicated to flavors and fragrances and includes offices, laboratories, a warehouse, a utility and workshop building, and a flavor-compounding plant. The first production unit was built to make flavors. And more construction is in the works: The next phase of the project will consist of fragrances production facilities.

Additionally, notes Hartmann, "We have [company] people in Shanghai and Canton, actively selling. We are investigating the best way of setting up compounding facilities for this growing market."

Although there is plenty of action in that region, he adds, "we are not neglecting other areas. For example, the U.S. is doing well, and there is growth in Europe."

Each of the regions tends to have individual characteristics. The split in the fragrances market is roughly equal between Europe and the Americas, but in the flavors business, it is significantly different. The explanation is simple, says Hartmann. "Look at the number of people. For this, the comparison is the U.S. and Europe, where the amount of use is comparable. Latin America is not as developed."

Even for food, however, globalization is becoming more of a trend. "Taste is still a local thing, but flavor can be produced anywhere in the world—it doesn't have to be produced in Bavaria or Greece."

And in supplying, no matter where, customer expectations as well as legal requirements are adding to the constantly increasing costs of product testing and complaints. This develops into a significant cost factor to be considered in the price calculation.

Apart from flavors and fragrances compounds, there are some quasi-commodity flavors and fragrances products in Haarmann & Reimer's product portfolio like *l*-menthol. Synthesis of this compound is one of the company's important achievements, Hartmann concedes, "to compete with natural menthol or citric acid and biochemistry products fermented from carbohydrates. Menthol prices may go up next year after a couple years of decline," following tightening availability of natural product from India and China, the big suppliers.

To help avoid being hit by commodity product cycles, Haarmann & Reimer is broadening its range of aroma chemicals to include specialties such as ultraviolet absorbers and cooling agents based on menthol technology for sunscreens and cosmetics.

Four years ago, the firm strengthened its small business in fine fragrances when it purchased, from Mallinckrodt, Créations Aromatiques, a designer house for fine fragrances. This has been kept as a business with a separate identity, and studios in Paris and New York City compete with Haarmann & Reimer's own studios in both cities. Two years ago, the company acquired the fragrance business of PFW.

And a similar sensitivity to separate markets and cultures is one reason the company's relationship with parent Bayer has worked so well, Hartmann believes.

"We have with Bayer an arm's length relationship," he says. "They love us, but leave us independence. Haarmann & Reimer is a company with its own history and success—it has grown and been profitable.

"In business as long as you are good, you have a lot of freedom. They realized early on that we are much closer to consumer goods, that our business has its own technical expertise, and that it is not in the interests of the business if it is just put into the big pot" along with all of Bayer's chemical operations. "Now, a lot of companies are decentralizing management to give people room to succeed. Bayer has always given us the autonomy." ☐

brings up the problem of indirect risk assessment, according to Pirages. To calculate the uptake of these compounds by humans, calculation of the uptake by other animals used for foods, such as beef and fish, is necessary. Pirages says there is some inconsistency in the way EPA calculates this indirect exposure that results in risks higher than are reasonable.

The principal problem she has with the indirect assessment is that EPA assumes that TCDD in the vapor phase is taken up by plants that are eaten by animals which are, in turn, eaten by people. She says the chemical properties of TCDD—particularly that it attaches to particles very strongly and that very little TCDD seems to exist in the vapor phase—make this "a questionable assumption." She also takes exception to EPA's use of 1978 dietary data to calculate approximate TCDD uptake because diets have changed significantly in the past 15 years, especially meat consumption.

The EPA characterization reviews the toxic effects of TCDD and related compounds, devoting a lot of discussion to carcinogenicity and to reproductive toxicity. The draft report concludes that all available data indicate that TCDD and related compounds increase cancer mortality. Similarly, EPA finds that exposing fish, birds, and mammals to these compounds causes several developmental defects, even at concentrations below those originally thought to have no effect.

Pirages is wary of extrapolating low-level effects in animals to humans because these same health effects have not been observed in humans who have been exposed to high levels of TCDD, either in industrial workplaces or by accident. If there are human reproductive problems caused by TCDD, she asks, why have such effects not been noted over the past 20 years when TCDD levels in humans were increasing? She thinks EPA has not taken a close enough look at the available human data in making some of the assumptions used in the draft study.

Pirages also thinks the agency did not provide enough information about its assumption in this chapter. "At a minimum, I would have liked to have seen in this chapter a greater discussion of the uncertainties inherent in their evaluation process. When they talk about the food chain exposures, I would have liked to have seen them acknowledge within this chapter that there are uncertainties in the assumptions that have been made, and the impact that these uncertainties would have on their estimates of risk. That way, a person reading this chapter could make [his or her] own judgment based on the information about those uncertainties," she says.

Concern over the toxicity of TCDD and related chemicals is high because people are already carrying significant levels of these compounds in their bodies. The report estimates total body burden for all dioxinlike compounds to be as high as 60 ppt. Significantly, this exposure is 500 times higher than what EPA proposed in 1985 as a safe level of exposure for a one-in-a-million risk of cancer. And it is still 150 times higher than the safe dose proposed in other parts of the TCDD risk assessment. EPA wonders if higher exposed populations, such as those that eat a lot of contaminated fish, might already be experiencing adverse effects from these compounds.

EPA is expected to complete its review of the draft risk assessment and issue the final report this summer. The considerable time taken to evaluate TCDD and related compounds will give the agency a benchmark by which to measure future assessments of toxic chemicals. If, however, there are still basic disagreements about the assumptions EPA has made, whether because of insufficient data or public policy considerations, risk assessment will continue to be a source of debate instead of a fundamental basis for environmental management.

David Hanson

NIH unit assesses predoctoral training programs

The National Institute of General Medical Sciences' (NIGMS) predoctoral training programs are doing a superb job of preparing graduate students for careers in biomedical research, a group of scientists and university administrators agreed during a recent discussion at the National Institutes of Health's Bethesda, Md., campus. The group advised NIGMS staff not to be too eager to alter the structure, organization, or operation of the 20-year-old effort.

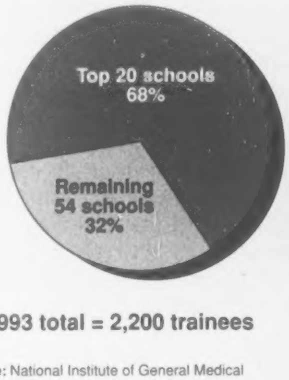
Yet, at the same time, the group acknowledged there is little concrete data regarding the subsequent careers of Ph.D.s who received support from NIGMS during graduate school. Evidence for the programs' apparent success is largely anecdotal. And many in the group worried about potential lack of diversity because the programs are concentrated at a limited number of schools.

Acting NIGMS director Marvin Cassman invited a dozen scientists from around the country to join the institute's advisory council's regular spring meeting for a discussion of NIGMS programs for supporting graduate students through training grants to universities. Under the authority of the National Research Act of 1974, NIH funds the majority of biomedical research training programs in the U.S. Within NIH, NIGMS programs represent about half of the total effort and NIGMS will spend about $80 million on predoctoral training grants this fiscal year.

"After 20 years, it's worth asking if we've got it right," Cassman told the group. "We want to hear your opinions and concerns." Cassman stressed that the discussion was just the beginning of a process of assessing NIGMS programs and that any suggested changes would be discussed in greater depth before being implemented.

NIH supports predoctoral students via a different mechanism than the National Science Foundation's graduate

Twenty schools enroll most predoctoral trainees



1993 total = 2,200 trainees

Source: National Institute of General Medical Sciences fellowships, which are awarded to individual students for use at the universities of their choice. NIH training support is awarded to institutions. The universities then fill their given number of slots with graduate students, most of whom are supported by the training funds for their first two years of study before being picked up under research grants.

At most NIH institutes, training programs are oriented toward clinical and disease research, said John C. Norvell, NIGMS assistant director for research training. NIGMS, in contrast, focuses on providing graduate students broad exposure across disciplinary lines. The four interdisciplinary predoctoral programs established in 1974 have changed little over time. They are cellular, biochemical, and molecular sciences; genetics; pharmacological sciences; and systems and integrative biology.

However, three new programs have been added since 1987. The molecular biophysics program, supported by funds for AIDS research and training, emphasizes structural biology and structure-based drug design related to AIDS. The biotechnology program was mandated by Congress in 1987 and involves interaction among industry and universities. The chemistry-biology interface program, initiated last year, is designed to bring more students from chemistry into the biomedical field.

NIGMS requires cooperation among faculty from different departments in providing course work and laboratory rotations, Norvell explained. The participating universities are also required to actively recruit students from underrepresented groups and to provide training in the ethical conduct of research.

Although only about 15% of the nation's biomedical graduate students are supported by training grants, the standards established by NIGMS programs have a ripple effect that gives the programs much broader influence, according to scientists participating in the discussion. Particularly valuable is the requirement for interdisciplinary work, said Marian Carlson, professor of genetics and development at Columbia University, New York City. "Graduate students need broad exposure and time for wide experience before choosing an area of specialization," she explained.

Manuel Navia, vice president of Vertex Pharmaceuticals, Cambridge, Mass., agreed that NIGMS guidelines have been valuable in helping to shape how young researchers are trained. "I've seen how NIGMS guidelines have had a great impact in clearing away the debris and allowing a student to pursue what is in his or her soul," said Navia, who has served as a reviewer for universities' training grant proposals.

Navia noted that his biotechnology firm is a consumer of the finished product of NIGMS training programs—biomedical researchers. "Overall, they have done a very good job," he said. Then Navia added this advice: "Be slightly conservative about tinkering with tremendously successful programs."

But Franklyn G. Prendergast, professor in the Mayo Foundation's department of biochemistry and molecular biology in Rochester, Minn., pointed out the lack of concrete data needed to really judge the programs' success. "A predicate for our discussion is that we have, in fact, produced a wonderful product," he told the group. "Do we know that? What criteria do we use? I find myself uncomfortable until I know."

Prendergast also cautioned the group to pay attention to the realities of the tight federal budget. "How many training slots do we really need?" he asked. "Are we deluding ourselves that in a zero-sum game we can support all these training sites?"

A draft report by the National Research Council's Committee on National Needs for Biomedical & Behavioral Research Personnel echoes Prendergast's concern. Under the National Research Act, NRC reports periodically to Congress on the need for biomedical researchers and the kinds of training that should be provided them. The most recent report, due to be released later this spring, endorses continued support of predoctoral training in the basic biomedical sciences but notes that "surprisingly few systematic studies are available of the career outcomes" of trainees.

The concentration of training grants within a relatively few universities was disturbing to many of the scientists and administrators. Just 10 schools, led by Harvard, Johns Hopkins, and Yale universities, receive 43% of NIGMS training grants. The group acknowledged that the skewed distribution may be due to merit rather than any inequity, but found the potential lack of diversity troubling.

"Of course, it is important to reward merit," said Susan Gerbi, biology professor at Brown University in Providence, R.I. "But it's important to broaden the base to maintain a diverse wellspring of ideas. You don't want all the trainees in the country hearing the same input."

Cornell University chemistry professor and vice president for planning John R. Wiesenfeld summed up the group's thinking about NIGMS's training effort overall: "If it ain't broke, don't fix it," he said. "I'm not sure the system is broke. However, I can guarantee 2004 will be a lot different than today. That the system is not broken today should give us cold comfort. The issue is: How well are the programs preparing biomedical scientists for tomorrow?"

Pamela Zurer

Broadest NIGMS programs enroll the most trainees

	Fiscal year							
Number of trainees	1986	1987	1988	1989	1990	1991	1992	1993
Cellular, biochemical and molecular sciences	825	907	895	833	743	774	780	755
Genetics	353	383	370	370	362	367	373	367
Biotechnology	—	—	—	83	162	274	298	314
Pharmacological sciences	253	258	259	262	288	276	276	279
Molecular biophysics	—	—	100	192	222	250	251	254
Systems and integrative biology	183	218	214	200	216	214	202	208
Chemistry-biology interface	—	—	—	—	—	—	—	23
TOTAL	1,614	1,766	1,838	1,940	1,993	2,155	2,180	2,200

Source: National Institute of General Medical Sciences

Plastics In Building And Construction

Use of these versatile materials grows moderately as manufacturers continue to push for wider acceptance in the building trades

Marc S. Reisch,
C&EN Northeast News Bureau

Plastics in the huge U.S. construction market continue to make inroads in areas traditionally held by such building stalwarts as concrete, wood, steel, and glass. Although the use of most plastics probably won't grow much more than the overall construction industry grows in the near future, some applications—such as for certain types of window frames and house siding—are expected to grow dramatically.

Plastics used in building and construction are valued at about 7%, or $5.6 billion, of the $80 billion total for building and construction materials used annually in the U.S., according to New York City-based consulting firm Frost & Sullivan. However, by weight, plastics account for less than 2% of new construction materials used each year, a figure that partly reflects the relative light weight of plastics.

Although the size and value of the overall U.S. construction industry is difficult to pin down, the Department of Commerce estimates that in 1993 the value of all new construction was about $460 billion. Include the value of additions, alterations, reconstructions, maintenance, and repair, and the value of all construction leaps to more than $750 billion.

Plastics may occupy a relatively small niche in this market, but they accounted for nearly 20%, or 12 billion lb, of the total 60.6 billion lb of all plastics produced in the U.S. in 1992, the most recent year for which such break-outs are available, according to the Society of the Plastics Industry, in Washington, D.C.

Among uses for plastics that are expected to grow only modestly are piping, flooring, vapor barriers, and bonding agents for wood products. However, some uses, such as building siding and window frames, are expected to grow more dramatically as plastics continue to supplant more traditional wood and aluminum materials in those areas.

Some visionaries expect to see wide use of composite plastic and fiberglass materials such as structural framing members, and even as components in civil engineering projects such as bridge decks. But high costs relative to costs of traditional materials limit these uses at present to specialized structures for which a client is willing to pay for a performance advantage that composites may offer.

Some plastic composite buildings already in use are, for example, those in which electronics manufacturers test their equipment to meet Federal Communications Commission (FCC) specifications. The plastic structures, free of metal, are suitable for all-weather equipment testing because the buildings are transparent to electromagnetic radiation.

But plastics still confront formidable barriers to gaining market share in building and construction uses. James Virosco, a principal with consultant firm Chem Systems, Tarrytown, N.Y., points out that the building industry is mature and slow growing. Housing starts are mediocre, he points out.

Virosco notes other barriers. Design standards for traditional wood and steel are well understood, he says; those for most plastics and the more exotic composites are not. So it will take time for architects to become comfortable working with plastics, and it will also take time for wider acceptance for plastics and composites use in building codes.

Richard M. Kossoff, president of consulting firm R. M. Kossoff & Associates, New York City, adds that a barrier to code acceptance of plastics is concerns about toxic smoke that may be generated when some plastics burn. He also thinks that the increased plastics use in building and construction is not growing as fast as once expected because there have been no major improvements in plastics to meet demanding building performance requirements. Talk some years back about the potential for carbon fiber plastic composites for structural framing never materialized because of the persistently high cost of carbon fiber.

More recently, performance problems have plagued the use of at least one plastic in new plumbing installations. The Washington Suburban Sanitary Commission, covering Montgomery and Prince George's Counties in Maryland, adjacent to Washington, D.C., joined other municipalities in banning installation of new polybutylene pipe because numerous breaks have caused flooding and damage to hundreds of homes (C&EN, May 23, page 9). Shell

Vista Chemical photo

General Electric photo

BASF photo

Amoco photo

Oil, which is the sole U.S. polybutylene producer, says it "regrets" the commission's action and is "reviewing" it. Polybutylene's share of the potable water pipe market is small, whereas polyvinyl chloride (PVC) and chlorinated PVC are much more widely used as plastic alternatives to copper.

Still, various plastics construction products have an edge because of their insulation properties, ease in handling, or better durability. In addition, although prices for most plastics have been moderate over the past few years, prices for wood products have soared.

Concern over the destruction of the northern spotted owl's habitat in the Pacific Northwest has prevented timber harvests on 7 million acres of federal and state lands. Meanwhile, demand has been high for wood to rebuild in devastated sections of southern Florida, Louisiana, and Hawaii where hurricanes wreaked havoc late in 1992.

Other natural disasters have also increased demand for wood and other building products: flooding in the Midwest along the Mississippi River during 1993, destructive wildfires in Southern California also in 1993, and the earthquake that did considerable damage in the Los Angeles area earlier this year. As prices for wood products have risen, plastics use has become more attractive.

Vinyl is used most widely

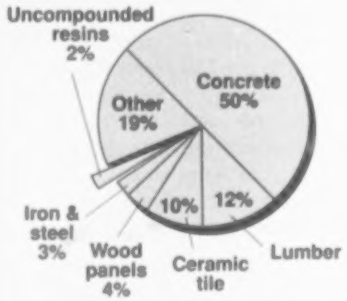
Plastics most widely used in building construction are the commodity-priced large-volume resins, such as PVC, polyethylene, and polystyrene. Some resins—considered engineering resins because of their higher performance, heat tolerance, and price relative to commodity resins—are also useful in building and construction products. Engineering plastics used in construction include polycarbonate, acetals, and polyphenylene oxide. However, these plastics are only used where their higher cost can be justified relative to the use of more traditional wood, glass, or metal materials.

PVC is now—and probably will remain for some time—the dominant resin used in building and construction. Its cost and performance make it among the most attractive replacements for wood and aluminum, particularly in the siding and window frame markets. A recent study from industry consultant Freedonia Group, based in Cleveland, pegs 1992 demand for all construction plastics at 12.7 billion lb. Of that, PVC accounted for almost half, 5.6 billion lb, and is expected to grow at more than 4% annually through 1997.

Phenolics are the second largest group of construction plastics, according to the Freedonia study. They are used for electrical devices and laminating plywood. Phenolics demand in 1992 was about 2.2 billion lb and growth is projected at just over 3% annually through 1997. Use of urea and melamine resins, the third most widely used plastics, totaled 1.4 billion lb in 1992. Used in the formation of countertop laminates and wood particle boards, demand for them is expected to grow almost 5% annually.

Polyethylene use totaled 942 million lb in 1992 and is expected to grow about 4% annually through 1997, according to

Plastics constitute 2% of building materials



Total 1992 use of building materials[a] = 446 billion lb

[a] Excludes resins used in applications such as water distribution, gas, and sewer systems pipe; telecommunication wire; sealants, caulks, and adhesives. **Source:** Phillip Townsend Associates, Houston, study for the American Plastics Council

Freedonia. This resin is often used for gas pipe and wiring conduit. Polyurethanes, used largely for insulation, are expected to grow more than 4% annually from 1992 demand of 875 million lb. A category of "other resins," including polycarbonates, acrylics, and polystyrene, represented an additional 1.6 billion lb in 1992 construction demand.

Consulting firm Frost & Sullivan identifies plastic pipe as the largest segment of the construction industry market for plastics. In 1992, the company says, the value of PVC's share of this market was nearly $1.8 billion.

According to Gary Draper, president of Vista Chemical's olefins and vinyl division, roughly three quarters of all PVC manufactured goes into the building and construction market. About 40% of the PVC sold goes into pipe for water mains, sewers, commercial applications and domestic water service. Another 25% goes to the manufacture of "profiles": residential siding and window frames. PVC coating for wire and cable accounts for another 5% of the PVC market. Current PVC demand is at its peak, says Draper, not only because of the peak demand for PVC during the building season from February to July, but also because of continued strength in the housing market compared with the 1991 recession.

The siding and window frame markets are growing the fastest. Draper says although PVC siding was applied mostly on existing homes, it has gained acceptance for use on new homes as well. Use of PVC siding in 1993 grew 17% from 1992, by Draper's reckoning, mostly because of its use in new construction.

PVC for use in window frames grew 10% in 1993, says Draper. High lumber prices along with a rebound in the housing market propelled PVC growth for windows, he says. PVC offers more insulating value compared with an equal thickness of wood, Draper points out, so the use of PVC windows offers an energy savings advantage to home buyers, too.

Draper expects continued growth for PVC in a developing market in sewer repair. Vista Chemical offers a flexible resin, Vynaprene, to produce "somewhat flexible" PVC pipes that can be pulled through cracked cast iron or concrete line to repair them. The PVC pipe receives a heat and pressure treatment in place, allowing it to expand inside the pipelines under repair, sealing any cracks and leaks.

Fred Sacks, marketing director for Occidental Chemical's vinyls division, says the PVC business is brisk now as this construction-driven polymer benefits from the recent strength of the construction market. He also estimates that about 75% of all PVC produced is tied to the construction market not only for pipe, siding, windows, wire, and cable, but also for roofing, earth-lining geomembranes for ponds and landfills, and floor tiles.

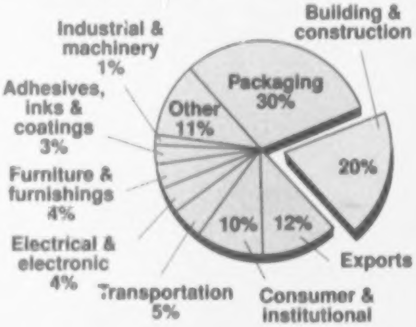
Sacks estimates that pipe represents 45% of the PVC market. He says that advances in manufacturing pipe allow the production of a pipe with a hard PVC inner and outer shell, but with a foamed PVC inner core. Such a pipe is lighter in weight than a solid PVC pipe, uses less material than the solid pipe, and thus is lower in cost. Pipe producers are making the foamed pipe in diameters up to 4 inches, and it is used in residential drainage systems. While Sacks admits the pipe may cost him some business initially because it uses less resin than the solid pipe, the foam-core pipe is a better product and will help PVC to continue to replace cast-iron pipe. With the strong housing market for PVC, producers of the resin are losing very little business because of the growing foam-core pipe business.

Advances by pipe manufacturers have also contributed to the growth of large-diameter PVC pipe for use in municipal sewer systems, says Sacks. Helically wound extruded profiles of PVC now compete with 24-inch to 48-inch cast concrete, he says. Manufacturers are also extruding similarly large, or even larger diameter, ribbed PVC pipes that have the strength to compete in the market for storm-size sewer pipe. Lighter than concrete or metal pipes, these PVC pipes allow for greater installation productivity, Sacks says. The PVC resin also better resists the effect of aggressive soils, such as Florida's high-sulfur soil, making for a longer lasting pipe system.

John Russ, vice president of Borden Chemicals & Plastics in Geismar, La., says construction demand for PVC is "really booming." PVC suppliers are unable to satisfy export demand for the resin. Export prices are on the rise because of the supply-and-demand situation, he says. Most of the advances in pipe and siding uses of PVC result from advances in processing. Resin producers are concentrating on providing a consistent, quality product, to help along those advances in processing.

A spokesman for Geon points out that existing home sales are much higher than new home sales. Thus, the remodeling market for PVC used in siding, new windows, and flooring is large. And the do-it-yourself market for vinyl products is growing along with the expansion of "home center" warehouse-type sales outlets throughout the U.S.

Building market used almost 20% of plastics made in 1992



1992 total plastics production = 60.6 billion lb

Source: Society of the Plastics Industry

Many types of plastics are used by the construction industry

Acrylic-styrene-acrylonitrile: A two-phase thermoplastic material combining styrene-acrylonitrile copolymer and acrylic rubber. Can be coextruded over acrylonitrile-butadiene-styrene for weatherability of window frames. Produced by General Electric, BASF, Monsanto, and Dow Chemical.

Acrylics: Thermoplastic resins of acrylic esters or methacrylic esters. Typical applications are in lighting fixtures and glazing. Producers include Rohm and Haas, Cyro Industries, and ICI Americas.

Acrylonitrile-butadiene-styrene: A thermoplastic derived from acrylonitrile, butadiene, and styrene. Used to a limited extent in window frames. Producers include General Electric, Monsanto, and Dow Chemical.

Chlorinated polyvinyl chloride: A thermoplastic produced by the post chlorination of polyvinyl chloride resin. Uses include hot and cold water pipe, and industrial liquid handling. Produced by BF Goodrich.

Ethylene-vinyl acetate: A thermoplastic copolymer of ethylene and vinyl acetate. Uses include wire and cable insulation, and sewer pipe repair. Producers include DuPont, Exxon Chemical, Union Carbide, and Dow Chemical.

Melamine and urea formaldehyde: Thermosetting resins formed by the condensation reaction of formaldehyde with melamine or urea. Applications include a laminating resin for countertops and adhesives for wood, particle board, and plywood. Producers include Georgia-Pacific, Borden, and American Melamine.

Phenolic: A heat-cured thermoset formed by the reaction of phenol and formaldehyde. Used in electrical devices and as a plywood adhesive. Producers include Borden, Georgia-Pacific, Occidental Chemical, Monsanto, and AlliedSignal.

Polybutylene: A semicrystalline thermoplastic formed by polymerization of 1-butene. Used in residential hot and cold water pipe, and under-floor hydronic heating systems. Produced by Shell Oil.

Polybutylene terephthalate: A semicrystalline thermoplastic polyester formed in a transesterification reaction between 1,4-butanediol and dimethyl terephthalate. Used to form countertops and sinks. Producers are BASF, General Electric, and Hoechst Celanese.

Polycarbonate: An engineering thermoplastic usually based on bisphenol A reacted with carbonyl chloride. Applications include window and skylight glazing. Major producers are Dow Chemical, General Electric, and Miles.

Polyethylene: A family of thermoplastic resins obtained by polymerizing ethylene. Applications include pipe and wire and cable covering. Producers include Union Carbide, Solvay, Eastman Chemical, Exxon Chemical, Dow Chemical, and others.

Polyphenylene oxide: A thermoplastic produced through the oxidative coupling polymerization of 2,6-dimethylphenol. Used to make roofing panels. Produced by General Electric.

Polystyrene: High molecular weight thermoplastic resins produced by free-radical polymerization of styrene. Uses include insulation and sheathing. Producers include BASF, Amoco, Dow Chemical, and Huntsman Chemical.

Polyurethane: A family of polymers based on the reaction product of an organic isocyanate with compounds containing a hydroxyl group. Uses include insulation and roofing systems. Raw material manufacturers include ICI Americas, Miles, Dow Chemical, and BASF.

Polyvinyl chloride: A thermoplastic resin produced by the polymerization of vinyl chloride. Uses include siding, window frames, and moldings. Producers include Occidental Chemical, Vista Chemical, Borden, Geon, and Georgia Gulf.

Thermoset polyester: The condensation product of an unsaturated dibasic acid, such as isophthalic acid, and a glycol. Uses include cultured marble sinks and spas. Producers include Aristec, Ferro, Owens-Corning, and Reichhold.

Geon has developed a technology that allows the use of fiberglass-reinforced PVC in prefabricated housing, the use of which has potential for growth particularly in developing countries. The system for such a structure, which gets structural support from concrete pillars poured into the PVC framework, is under license to Royal Plastics in Toronto, Canada.

A variant on PVC, chlorinated polyvinyl chloride (CPVC), is widely used in high-temperature water distribution systems. BF Goodrich is the only U.S. supplier of the material. According to Frank J. Copa, the company's industrial systems senior marketing manager, growth prospects are good for CPVC in industrial applications as well as in residential housing applications for the pipe. The excellent corrosion resistance of CPVC over a wide temperature range, along with a good mix of mechanical properties, would give CPVC a better service life in chemical process industry than carbon and stainless steel now offer, he says.

Goodrich's CPVC resins are now available from pipe manufacturers in ½-inch to 18-inch diameters. Because the material has good flame retardance and low smoke generation, CPVC may also be used in light-service water sprinkler systems, says Copa.

PVC is also used in the manufacture of geomembranes to line ponds and waste disposal sites, and for roofing. HPG International, the former plastics division of Hüls America, produces the wide sheets for these uses along with a line of polyolefin-based sheet. According to HPG president John P. Dellevigne, the roofing PVC business is doing well now, but the business tends to be cyclical, dependent on the ups and downs of the construction market.

Because neat PVC resin tends to be brittle without the proper additives, a number of PVC additives help extend the performance range of PVC. Lawrence Brecker, vice president of the polymer additives group for Witco, says his company is a leading provider of methyl, butyl, and octyl organotins used as heat stabilizers in PVC resins. The additives improve the resin's long-term weatherability.

Brecker says the company also supplies mixed metal heat stabilizers for flexible PVC, such as calcium/zinc- and barium/zinc-based compounds used in wire, cable, and flooring formulations.

Continued on page 28

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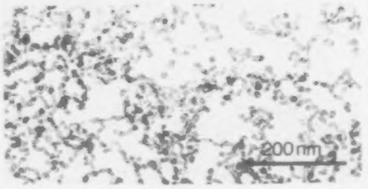

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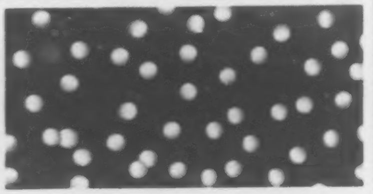

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CIRCLE 18 ON READER SERVICE CARD

Construction demand for plastics rising 4% annually

Millions of lb	1992	1997	% average annual change
Polyvinyl chloride	5,638	6,970	4.3%
Phenolics	2,252	2,630	3.2
Urea & melamine	1,404	1,770	4.7
Polyethylene	942	1,140	3.9
Polyurethane	875	1,085	4.4
Other resins	1,586	1,925	2.0
TOTAL	12,697	15,520	4.1%

Source: Freedonia Group

Value of PVC exceeds all other resins in construction

$ Millions	Estimated 1992	Projected 1995	% average annual change
Polyvinyl chloride	$1,792	$2,075	5.0%
Phenolics	1,122	1,235	3.3
Polyurethanes	925	1,059	4.6
Polyethylene	435	512	5.6
Polystyrene	330	383	5.1
Urea & melamine	272	297	3.0
Acrylics	256	298	5.2
Other	515	662	8.7
TOTAL	$5,647	$6,521	4.9%

Source: Frost & Sullivan

Witco was formerly a big supplier of cadmium-based stabilizer, but because of toxicity concerns over heavy-metal use, the company has discontinued heavy-metal additives. Other additives the company supplies for PVC are lubricants that ease the processing of PVC and blowing agents for PVC foam.

Jim Souder, plastic additives marketing manager for Rohm and Haas, says the acrylic additives his company supplies to PVC processors help improve both the impact resistance and the weatherability of PVC siding, window frames, and pipe. The acrylic additives, used at 5 to 10% of the weight of the final products, also aid in the melting and fusion of vinyl compounds prior to extrusion.

Elf Atochem competes with Rohm and Haas as a supplier of acrylic PVC additives, as well as with Witco as a supplier of organotin heat stabilizers. David Fultz, vice president and general manager of Elf Atochem's additives division, says the company has ongoing organotin research programs to improve the weatherability of dark-colored PVC so that vinyl can compete with dark-colored aluminum window frames. "The key to making PVC work," says Fultz, "is the additives."

Where dark-colored, all-PVC window frames are still not viable, Elf Atochem offers an option. An Elf Atochem spokesman says the company's polyvinylidene fluoride (PVDF) can be laminated or coextruded over PVC to extend the performance of dark-colored PVC window frames that might otherwise tend to crack because the dark colors allow greater heat buildup than PVC can usually withstand. Other construction uses are solid PVDF pipe—which, at five to 10 times the cost of comparable PVC pipe, can replace stainless steel drain pipes where corrosive liquids must be handled, such as in chemistry labs.

Other suppliers of PVC additives include Lonza and Uniroyal Chemical. Lonza's lubricants aid in faster processing of PVC siding, for instance. According to Tom Gazel, Lonza market-

Piping is largest segment of construction market for plastics

$ Millions	Estimated 1992	Projected 1995	% average annual change
Pipes, fittings & conduits	$1,662	$1,904	4.6%
Resin-bonded woods	1,130	1,238	3.1
Insulation	1,047	1,195	4.5
Siding & paneling	336	426	8.2
Flooring	467	522	3.8
Window profile extrusions	168	211	7.9
Vapor barriers	128	143	3.8
Glazing & skylights	397	503	8.2
Other	312	379	6.7
TOTAL	$5,647	$6,521	4.9%

Source: Frost & Sullivan

Worker tests efficacy of Air Products & Chemicals' polyurethane foam additives.

ing manager, the company offers both ethylene bisstearamide and glycerol ester lubricants. Uniroyal says its PVC blowing agent business is doing well as use of foam-core pipe grows. According to Casey Leone, specialty chemicals marketing manager, the company's azodicarbonamide blowing agents are also used in window frames, decorative moldings, and resilient vinyl flooring.

Although PVC may be making inroads into areas held by traditional building materials, some plastics are trying to displace PVC itself in some building and construction applications. General Electric, for instance, is promoting use of its acrylonitrile-butadiene-styrene (ABS) coextruded with colored acrylic-styrene-acrylonitrile (for weatherability) for use in window frames and siding. Deep colors of GE's coextruded plastics perform better in hot climates than competing PVC, says industry manager Paul M. Conroy. The materials have higher dimensional stability and resist heat buildup better, he says.

GE's materials are cost competitive with both aluminum and PVC, Conroy says, and he's confident they will find their niche as an alternative to those materials as well as to wood. Conroy estimates half of all window frames made today are made of wood, with aluminum at about 30% of the market and vinyl accounting for the remaining 20%. Currently, GE's penetration into the market is small, he admits.

Bob Ackley, president of the Davis-Standard division of Crompton & Knowles, says the company has frequently supplied multilayer extrusion equipment necessary for the types of siding and window frame coextrusions that GE is promoting. The technique is more widely used in food packaging, as well as in the production of automotive parts, he says. More recently, the technique has been applied to construction industry materials. For instance, vinyl window frames are being coextruded with a harder vinyl core and a soft vinyl outside where the frame and glass meet, providing a better seal between the vinyl and glass.

Polyurethane foam use

Polyurethane rigid foam insulation for roofs and walls was a $925 million business in 1992, estimates Frost & Sullivan. James R. Steiner, Miles Inc.'s lamination market manager, says Miles supplies the precursor isocyanates and polyols that manufacturers of the foam-board insulation need. Use of the foam in the housing market has increased along with housing starts, but its use in commercial buildings, either to insulate roofs or as insulation behind metal facings, has not been as strong.

Miles also supplies precursors for foamed-in-place insulation, says Steiner, to insulate garage and residential doors, for instance. Reaction injection molded polyurethane is also seeing use in door and skylight frames, in place of wood, vinyl, or aluminum.

Dow Chemical is another supplier of polyols and isocyanates, which are used to make polyurethane insulating board. Dow also supplies users with precursors for foamed-in-place polyurethane insulation in doors, says Cindy Elliott, marketing manager for rigid-foam applications. A new development is the use of foamed-in-place urethane to insulate large industrial refrigeration units and warehouses. Growing, too, on a small base, is the market for consumer-applied polyurethane insulation, which is dispensed from a pressurized can and sold at hardware stores and home centers.

Historically, polyurethane insulation has required the use of a chlorofluorocarbon (CFC) blowing agent in addi-

Continued on page 34

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CIRCLE 2 ON READER SERVICE CARD

General Electric, DuPont push construction plastics to limits in model homes

General Electric is a major plastics producer that would also like to be a major supplier to the building and construction market. About five years ago, the company splurged on the construction of a 3,000-sq-ft model home in Pittsfield, Mass., where the company's plastics business is headquartered.

About 30% of the house consists of plastic. According to GE, that amounts to 45,000 lb of plastic—and that is because GE set out to push the limits for this house, which contains many developmental construction products not widely in use today. Most new residential construction contains no more than 5% plastic, says GE's building and construction industry manager, Walter J. Bilinski, despite the seeming proliferation of plastics in flooring, molding, countertops, and plumbing.

But GE's new house contains a plastic roof. Very few homes today have such a roof. Bilinski says Eiger Building Products, Miami, Fla., has begun commercializing roofing sheets that look like cedar shake shingles made out of GE's polyphenylene oxide resins. Siding and window frames on the house are made from dark-colored acrylic-styrene-acrylonitrile coextruded over acrylonitrile-butadiene-styrene for better performance than polyvinyl chloride, says GE industry manager Paul M. Conroy.

Plumbing systems include polybutylene terephthalate sinks made from GE's resin. Window glazing at the house entry features GE's polycarbonate for security purposes. The plastic windows cannot be broken as easily as those made from more traditional glass.

Plastics in the house offer advantages, says Conroy. For example, they replace wood in window frames and siding, their thermal efficiency saves energy, and the low maintenance qualities endear them to consumers. In addition, notes Conroy, plastics are versatile, and so they can be designed to mimic the appearance of traditional materials or allow designers the freedom to come up with new designs.

Although Conroy is confident that plastics will continue to make inroads into the building and construction

C&EN staff photos

tion to the polyol and isocyanate components. Both Miles' Steiner and Dow's Elliott have noted that CFCs, implicated in the destruction of Earth's protective ozone layer, have all but been eliminated as polyurethane blowing agents. Thomas J. W. Gellrich, Elf Atochem's business manager for foams and specialties, says CFC blowing agents for polystyrene foam have been replaced as well. A number of fluorochemicals with low or no ozone depletion potential have replaced the CFCs, he says.

Hydrochlorofluorocarbons (HCFC) 141b and 142b are currently the best alternatives to CFCs, but they will be phased out by 2015, says Gellrich. Under development are fluorochemicals with no ozone-depleting potential, such as hydrofluorocarbon 134a, he says. Pentane, a CFC substitute, is flammable and yields a foam with poor insulating properties, says Gellrich. Another CFC substitute, cyclopentane, is flammable, does not have good insulating properties, and is also a volatile organic compound (a precursor of atmospheric smog), he says. Still another alternative blowing agent, carbon dioxide, is "okay," says Gellrich, but it also yields a foam with poor insulating properties.

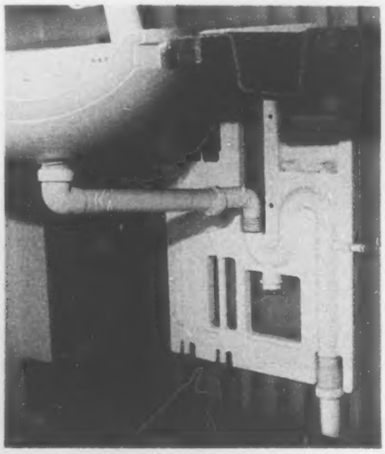
Peter Sullivan, industrial products business manager for Amoco Foam Products, says his company's expanded polystyrene (EPS) foam boards have been free of CFCs since January 1990. Like other manufacturers, Amoco declines to identify the specific blowing agent the company uses to convert its own EPS beads into foam boards. Amoco EPS boards are available in thicknesses of ½ to 3 inches, and provide insulation below ground around foundations, along sidewalls, and under roofing. A variation of Amoco's foam board is available with 50% recycled content, half of which is postconsumer material. It has almost the same insulation values, but shows a slight degradation in compressive strength compared with board made from virgin resin, says Sullivan.

Huntsman Chemical supplies block molders with EPS beads to form foam blocks and sheets. Marketing development manager Jim Shannon, says that years ago, molders made undifferentiated 4- × 8-foot EPS board stock to insulate buildings. Now, EPS boards are engineered into value-added "systems" in which the EPS sheet may be laminated to roofing and wallboard for insulation.

In a developing application, two 4- × 8-foot sheets of wood oriented strand board sandwich an EPS foam panel to provide a structural insulated panel system that may find use in the construction of new homes. The EPS panel has prerouted ducts to allow for electrical wiring and plumbing. The panel offers a 33 to 50% energy savings over conventional construction, and is cost competitive with conventional construction as well, says Shannon. However, this technology has not yet gained wide acceptance. Shannon sees further resistance ahead for the technology from carpenters' unions because a "house can go up in four days"—much less time than it takes using ordinary materials.

BASF also produces EPS beads, which Tom Greeley, business development manager, agrees are used mostly to form roof, wall, and foundation insulation panels. A developing use for EPS is in the construction of forms for concrete foundations. Two basic systems are used. One utilizes two EPS sheets separated by a space and held together with plastic ties to outline a foundation form. A builder pours concrete between the sheets, and the EPS is left in place. In a second system, a builder can mold a foundation with EPS building blocks. The builder fills the blocks with concrete to form a load-bearing foundation.

Almost one third of GE's new house is made of plastics.



markets, he acknowledges it will take some time before plastics use approaches anything near the 30% level in the GE model house. Wood and wood-based chip and flake boards will still find wide use as building studs, siding underlayment, and roofing decks. These materials are used in the GE house as well.

GE is not the only plastics manufacturer to build a "concept" house to showcase plastics used in construction. DuPont teamed up with builder Segal & Morel in the northern New Jersey town of Chester to build a 3,600-sq-ft two-story home. DuPont products used to construct the house include nylon resins for electrical outlets and switches, Corian acrylic for countertops and tub surrounds, a synthetic slate roof containing polyethylene pulp, Tyvek polyethylene fiber air-infiltration house barrier wrap, and laminated glass fabricated with polyvinyl butyral resin.

DuPont is also a big supplier to the home furnishings industry, so the home showcases domestic goods such as carpeting, upholstery, sheets, comforters, and curtains containing DuPont polyester and nylon fibers.

One advantage of these systems is that they retain moisture around the concrete, allowing for a longer and stronger cure. Also, since the EPS remains in place, it saves the labor of removing the wood forms used in conventional poured-foundation construction. In addition, because the EPS stays in place, it provides long-term insulation. And in earthquake-prone areas, the EPS acts as an energy absorber and earth stabilizer, says Greeley.

Although Frost & Sullivan estimates the size of the EPS market at $330 million, the polyethylene market is somewhat larger at $435 million. Christer Rundlof, Unipol polymers business manager for Union Carbide, says polyethylene is used for potable water distribution, natural gas distribution, and cable conduit. Because the plastic alone is not flame retardant, it is not often used inside buildings. Rundlof claims that polyethylene is a cost-efficient material to produce, extrude, join, and maintain. He estimates that polyethylene has captured 75 to 80% of the natural gas distribution market.

Because PVC becomes brittle at low temperatures, Rundlof thinks polyethylene could eventually replace PVC in sewer pipes. Polyethylene "has a much lower brittleness temperature than PVC," he says. And just as at least one

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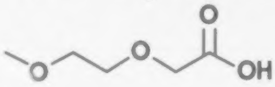
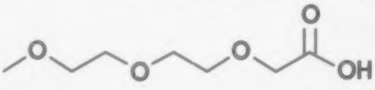


3.6.9-Trioxadecanoic acid



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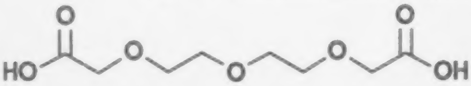
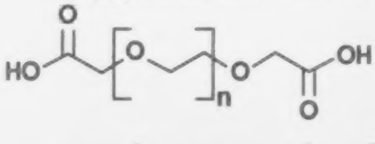


Polyglycol diacid (n = 10 - 12)



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CIRCLE **14** ON READER SERVICE CARD

PVC producer, Vista, says PVC can be used to seal and reline old concrete and steel water and sewer pipe, polyethylene can also be used for the same purpose, says Rundlof.

Steve Sandstrum, pipe resin industry manager for Solvay Polymers, says increasing demand for large-diameter pipe for commercial and industrial use and continuing growth for natural gas distribution have kept the construction market for polyethylene fairly robust. One growing commercial use for polyethylene has been as a conduit for fiber-optic telecommunications lines being installed across the U.S. A burgeoning area for polyethylene use is in large-diameter pipes (up to 60 inches in diameter) in distribution systems for potable water.

Another potential growth market is polyolefin-based wire and cable jacketing. According to Grace Waag, Union Carbide's business manager for flame-retardant wire and cable materials, additives and fillers make the polyolefins flame retardant without the use of halogens. In contrast to halogen-containing coated wire such as PVC, the alternative-coated wire would give off fewer emissions and no toxic or corrosive gases in the event of fire. The cost of the jacketing materials is available at a 10 to 25% premium to conventional jacketing material, "but it is a small price to pay for fire safety, we think," says Waag.

Another polymer resin used in construction, melamine, is widely employed in the production of high-pressure laminates such as Formica-brand laminate and in low-pressure laminates such as wood particle board. Gordon Ruhf, process chemicals marketing director for Cytec Industries, expects the use of melamine adhesives to grow as lumber becomes more scarce in the U.S. and more scrap wood is converted into various types of particle boards.

Ruhf also sees a growing market for melamine crystal used as a scavenger in urea formaldehyde glues to prevent outgasing of toxic formaldehyde. Cytec produces melamine in a joint venture with Dutch chemicals producer DSM called American Melamine Industries. The partners split the output and individually market the melamine.

Workers (above) prepare vinyl siding for weatherability and toughness testing; polystyrene-insulated pipe circles a poultryprocessing plant.

Rohm and Haas photo

Dow Chemical photo

Both acrylic and polycarbonate compete as glazing materials to replace glass in the building and construction market. Hal Ivy, marketing programs manager for ICI Lucite sheet, a business ICI Americas recently acquired from Du-Pont, says acrylic glazing is largely used as a security barrier. It is also used in lighting grids and skylights.

Acrylic sheet is used in thermoformed bathtubs and spas as well. Once the tub or spa is formed, it is backed with polyester-reinforced fiberglass to give the unit rigidity.

Ferro Corp. supplies polyester gel-coat resins to coat fiberglass-reinforced tub and bath units. According to Ben Froelich, Ferro director of sales and marketing, Ferro purchases an isophthalic-acid-containing polyester resin from a supplier such as Ashland Chemical and then adds color and diluents. The gel coat may then be sprayed to form a smooth-finish colored sink or tub. Jim Luke, gel-coat operations manager for Ferro, says gel-coat finished fixtures compete not only with the acrylic-sheet-formed bath fixtures, but also with those made of more traditional enameled steel.

Douglas G. Powell, building and construction marketing manager for polycarbonate producer Miles, says polycarbonate is a relatively small player in the construction market. He estimates that about 120 million lb of polycarbonate are used annually for glazing in skylights, vandal-resistant windows, and outdoor signs. The cost of polycarbonate somewhat limits its growth potential, but where its clarity and break resistance are valued, polycarbonate use will grow. One potential new market is for clear blocks, that when made out of lightweight polycarbonate, reduce installation cost and the fatigue of installing the much heavier glass blocks.

Another new polycarbonate market is corrugated sheet to replace fiberglass-reinforced polyester sheets now used to cover structures such as greenhouses. Powell says corrugated polycarbonate has superior strength, weatherability, and light transmission when compared with the fiberglass sheet. Still another new polycarbonate product is a double-wall sheet, with half the thermal conductivity of glass, for use in greenhouses and residential applications.

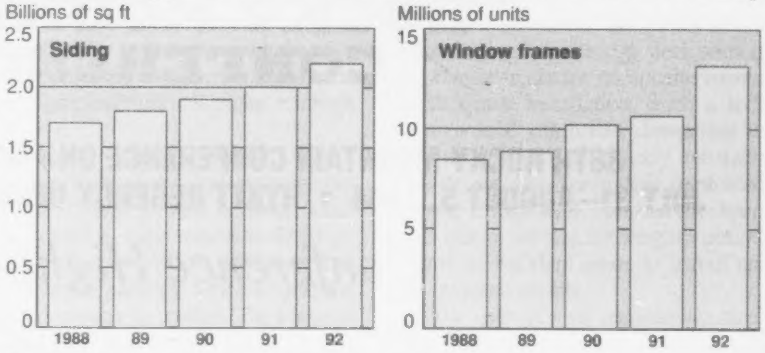
Strict new building codes in hurricane-plagued southern Florida will require tougher glazing to resist the impact of debris flung by a storm's winds. Polycarbonate may be able to compete in this market because of its excellent impact resistance, says Powell.

Building codes are also a consideration in GE's introduction of polyphenylene oxide (PPO) into roofing tiles. Roofing materials that contain plastic are "barely detectable," in the market now, says building and construction industry manager Walter J. Bilinski, but GE hopes that will change as new codes in communities along the California coast give PPO roofs an edge. Fires

Continued on page 41

Continued from page 36

Vinyl siding, window frame shipments have risen steadily



Source: Vinyl Siding Institute, division of the Society of the Plastics Industry

devastated many communities there last year. Flammable cedar shake roofs contributed to the fires' spread.

PPO panels can be made to look like wood and can easily achieve minimum fire-resistance ratings, whereas cedar requires special treatment to achieve that rating. In addition, Bilinski says he thinks PPO installation systems will ultimately achieve the highest fire-resistance rating, class A. The PPO panels are easy to install and save labor. One manufacturer's PPO panel requires only five nails to install, whereas an installer would have to drive 26 nails to get comparable coverage with individual cedar shake shingles.

With a cost of about $170 for materials to cover 100 sq ft, PPO roof tile is less expensive than slate (a look it can also achieve), competitive with cedar shake, and somewhat higher than clay tile. Bilinski figures that about $1 billion goes to purchasing those competitive residential roofing materials annually. He hopes to see PPO roofing materials gain a considerable share of that market.

Another residential market GE hopes to tap is the countertop and sink market. Formica Corp. is now distributing GE's polybutylene terephthalate (PBT) sheet, a thermoplastic polyester that competes with melamine-based laminates, thermoset acrylics, and other thermoset polyesters. Because it is a thermoplastic material, PBT can be thermoformed into a sink, allowing for seamless joining of the sink with a PBT countertop, says Mark H. Hindal, GE Plastics business leader. The material's use is only in its infancy in the $1.3 billion countertop

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CIRCLE 33 ON READER SERVICE CARD

market, but Hindal also sees a potential market for PBT sheet in bath, shower, and tub surrounds.

Composite inroads are tentative

A small market exists today for all-plastic buildings. According to David Goodwin, product manager for the Composite Technology unit of W. R. Grace, the company can provide complete buildings of plastic for use in very corrosive environments, as well as for electronics industry companies that must conduct FCC tests of electronic equipment in environments free from electromagnetic radiation.

The Grace unit has annual sales of between $13 million and $16 million of composite plastics and fiberglass components for building and construction. In addition to all-plastic buildings, the Grace unit supplies fiberglass-reinforced polyester or vinyl ester panels to replace aluminum or steel panels that have corroded, or for new construction. It can also supply plastic-fiberglass structural beams as one-for-one replacements for steel beams in both new and existing buildings. The beams are so strong because they are "pultruded," a process by which continuous glass fiber is pulled through a resin bath. The polyester, vinyl ester, or other resin is then polymerized as the plastic-fiberglass matrix is pulled through a steel dye.

Composites such as those Grace's composite technology unit supplies occupy the middle ground between what Steve Borleske, new business development manager of DuPont advanced material systems, calls the low-end and the high-end composite market. The low end includes fiberglass composite baths and spas, and the high end includes advanced aerospace and sporting goods components.

In addition, DuPont is studying fiberglass or carbon-fiber-reinforced polyester or vinyl ester for use in "middle-ground" civil engineering structures. Systems to repair or build bridges and roadways are markets DuPont is targeting, says Borleske. The company hopes to make its mark as a manufacturer of large composite parts using other manufacturers' fiberglass, vinyl esters, or other materials.

Borleske envisions the possibility of prefabricating large bridge deck sections of corrosion-resistant composite materials for quick installation. Such a technique would minimize downtime on busy urban bridges, quickly returning roads to service. Traditional reinforced-concrete bridge deck construction keeps roads out of service for lengthy periods of time as builders labor to install and cure concrete on site.

In the case of civil engineering structures, DuPont is targeting customers such as state departments of transportation. But while university- and government-sponsored research has gathered considerable data on composites for infrastructure improvements, the technology does not have a long track record, Borleske admits. Still, DuPont thinks it will ultimately be able to show federal and state governments that plastic composites will offer both installation and life-cycle costs comparable to or better than existing techniques. ☐

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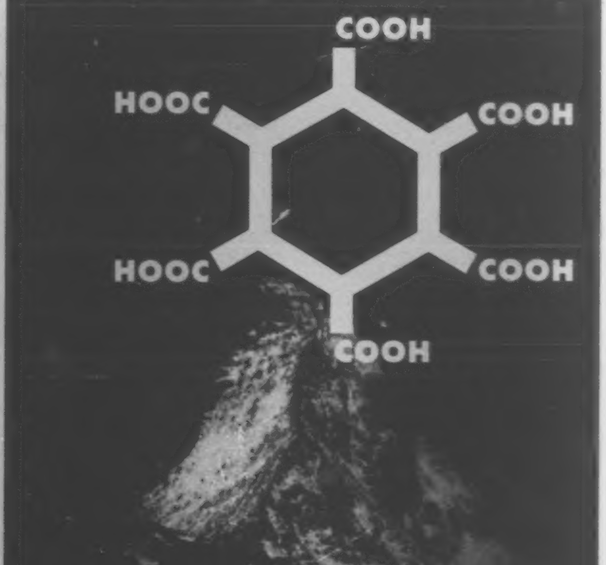

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CHEMICAL & ENGINEERING NEWS

C&EN

JUNE 13, 1994

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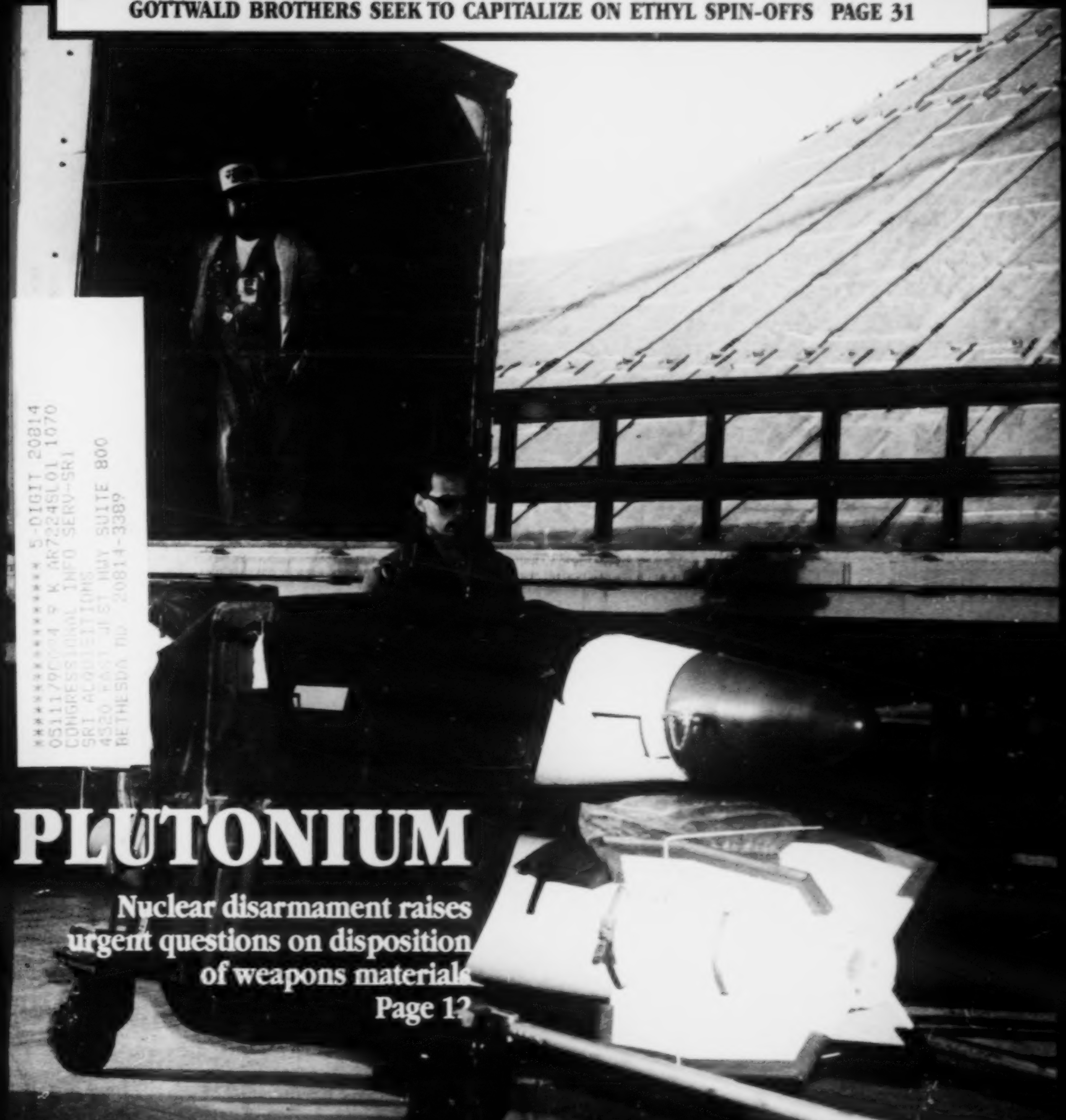
GOTTWALD BROTHERS SEEK TO CAPITALIZE ON ETHYL SPIN-OFFS PAGE 31



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PLUTONIUM

Nuclear disarmament raises urgent questions on disposition of weapons materials
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CHEMICAL & ENGINEERING NEWS

C&EN

JUNE 13, 1994

NEWS OF THE WEEK

- A detection technique for NMR signals—one that uses mechanical force sensing—provides unprecedented sensitivity and spatial resolution. **Page 6**
- J. T. Baker Inc. is put up for sale by parent Procter & Gamble, the latest in a series of ownership changes in the lab chemicals area. **Page 7**
- Based on two recent discoveries, chemists at the University of South Carolina have begun the first studies of the biological activity of unsubstituted buckminsterfullerenes. **Page 7**
- The "dirty laundry" fight rages on between Unilever and Procter & Gamble over Unilever's popular new detergent formulation for European markets. **Page 8**
- In a novel move to encourage collaboration and dissemination of innovative projects, NSF brought together educators working on NSF-sponsored undergraduate curriculum projects and publishers. **Page 8**
- Planned sale of securities tied to Lyondell stock is postponed by Arco pending completion of investigation into Lyondell's alleged noncompliance with emission regulations. **Page 9**

COVER: Workers transport nuclear bombs in preparation for disassembly and plutonium removal at Department of Energy's Pantex site near Amarillo, Tex.

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BUSINESS

Bruce and Floyd Gottwald, the two brothers who built Ethyl Corp. into a diversified chemicals firm, position spin-off companies for growth, say splitup will focus investor attention on the value of each company's assets and business. **Page 31**

Biotech company Cytogen and its two-year-old R&D funding vehicle, CytoRad, may be heading toward litigation to sort out disagreements over each other's contractual obligations. **Page 34**

GOVERNMENT

Reauthorization of the Clean Water Act remains in doubt because diverse groups—including chemical industry—object to provisions that address discharges into groundwater as well as unfunded mandates, wetlands designations, and risk assessment. **Page 37**

SCIENCE/TECHNOLOGY

Newly developed catalytic monoclonal antibody catalyzes a cationic cyclization reaction, giving high yield of one specific product instead of a complex mixture of products. **Page 43**

NEWS FOCUS

Disposal of plutonium from dismantled nuclear weapons and in spent nuclear reactor fuel rods is a large, complicated, and urgent problem for the U.S. and Russia. Page 12

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LETTERS

Science's costs, benefits

Bryan J. Cook wonders whether science really benefits humanity (C&EN, May 16, page 5). He deplores that nobody in C&EN has addressed this issue in the past two years, which leads me to write this letter. He blames science for not eliminating wars, but for invariably creating new dilemmas. Cook quotes Ralph Waldo Emerson, who in 1841 said "society never advances."

Cook could easily avoid the dilemmas that science has created by never using a bicycle or a car; never crossing a metal bridge; and avoiding all medicinals that cure tuberculosis, plague, glaucoma, and high blood pressure. In addition, he should bypass antibiotics, medical care, and all hospitals. He could return to the infant mortality figures during the London plague and the wheat yields per acre of the same year. Not only the dilemmas of electric power and biotechnology, but also the steam engine should be avoided, along with "chemicals," man-made food additives, and purified drinking water.

An excellent book by Paul R. Gross and Norman Levitt, "Higher Superstition: The Academic Left and its Quarrels with Science," recites the many absurdities about science that flow freely from postmodernism, departments of sociology and English, and other nonscientists equally convinced that science does not "really benefit humanity." While these folks all appear to use electric light and take aspirin, they seem secure in the knowledge that these benefits really come from rain forest shamans.

Edwin A. Matzner
St. Louis

Bryan J. Cook's comments are right on target, and he is not alone in his views. During my 39-year career teaching chemistry and chemical engineering at the University of Mississippi, I not only expounded on the basic laws of science and engineering, but I also introduced and emphasized four fundamental laws, which I named for convenient reference.

First, the law of interconnectedness: Everything is connected to everything. Second, the law of diverse effects: Every action results in both advantages and disadvantages. Third, the law of choices and consequences: The freedom to make choices does not include the freedom to choose the consequences of the choices. And fourth, the law of cascading effects: Every action results in an infinite number of cascading effects. That is, every action not only has an immediate or primary effect, but also results in secondary, tertiary, and continuing effects ad infinitum.

Katherine Ann Porter in her book "The Ship of Fools" has one of her characters say (not quoted exactly): "Probably as much harm has been done in doing good as good has been done." Some years ago, ethicist Leon Kass, in an excellent newspaper article on "America and the Future of Man," said in part: "Man's victories have been expensive—it seems that our predicaments are the corollaries of our greatest successes."

When there were fewer people, and they were less concentrated, it may not have made too much difference what was done (that is, it could be tolerated). Today, that is no longer the case. An examination of people's actions through history suggests to me that the net total advantages of a discovery or "advance" are almost balanced by the net total of the disadvantages. Even though people have demonstrated that they have little ability to see into the future, a serious effort must be made to analyze our actions in an attempt to make sure that the net advantages will probably outweigh the net disadvantages. I cringe daily when I see the business-industrial world focusing so much attention on last quarter's "bottom line" and on "downsizing." The world needs more of Cook's thinking.

Frank A. Anderson
Oxford, Miss.

Recently discovered elements

In Darleane Hoffman's periodic table (C&EN, May 2, page 25), the newly discovered elements are shaded in blue. They are Tc (atomic number 43), Pm (61), At (85), Fr (87), Np (93), and all higher atomic numbers. These elements are all man-made, or are present in Earth's crust in extremely low amounts because they are very unstable.

The differences between their atomic numbers form an intriguing pattern,

$$\begin{aligned}
61 &= 43 + (2 + 6 + 10)\\
85 &= 43 + (2 + 6 + 10) + (\phantom{2 + 6 + {}}10 + 14)\\
87 &= 43 + (2 + 6 + 10) + (2\phantom{{} + 6} + 10 + 14)\\
93 &= 43 + (2 + 6 + 10) + (2 + 6 + 10 + 14)
\end{aligned}$$

since the integers that you need to add to relate Tc to the rest are the same as the numbers of electrons in closed electron shells (s^2, p^6, d^{10}, f^{14}).

This is presumably a coincidence because I know of no relationship between nuclear stability and electronic configurations. Or could there be?

Peter J. Sadler
London

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U.S. And Russia Face Urgent Decisions On Weapons Plutonium

Possibility of terrorist diversion, outright theft drive move for new safeguards, choice of optimum disposal methods

Bette Hileman, C&EN Washington

The current international crisis involving North Korea's possession of plutonium—possibly enough to make one or two nuclear weapons—is coming at a time when the U.S. and Russia are worrying over what to do with all the plutonium they remove from their declining nuclear arsenals.

At the heart of the issue is the radioactive silvery metallic element named after the planet Pluto. Its primary danger lies in its fissionability with neutrons to yield atomic energy, and thus its use in nuclear weapons. Although the element occurs in nature only in minute quantities, plutonium is created in the uranium fuel rods of nuclear reactors. Accumulating amounts of plutonium from the world's nuclear power plants, as well as increasing stores of plutonium from dismantling nuclear weapons, have created a quandary for humankind.

It's become painfully clear that although nuclear disarmament offers great hope for improving world security, it also involves serious risks, not the least of which is the disposition of the radioactive isotopes used in nuclear weapons. With the end of the Cold War, the U.S. and Russia have agreed to drastic reductions in the number of nuclear weapons they possess. Thousands of warheads have already been removed from delivery systems, and many have been dismantled, meaning that the fissile materials—highly enriched uranium and plutonium—have been taken out. By 2003, a total of 40,000 weapons may have been dismantled, leaving about 5,000 on each side. In the process, as much as 150 metric tons of plutonium will be removed from the weapons.

This surplus plutonium poses a "clear and present danger to national and international security," warns a National Academy of Sciences (NAS) study released in January, titled "The Management and Disposition of Excess Weapons Plutonium." Indeed, it poses a threat at least as great as the one posed by North Korea's possession of a relatively small supply of plutonium.

In many respects, fissile materials outside warheads pose more security problems than those in intact weapons. As long as such materials are contained within weapons, they are heavily guarded by the military complexes on each side. Once they are removed, they are not necessarily under such control—unless they are being reserved for future military use.

For countries or terrorists who want to manufacture nuclear arms, the stumbling block is obtaining the fissile materials. It is very expensive and technologically demanding to set up facilities to make highly enriched uranium or to build nuclear reactors and reprocess the spent fuel to produce plutonium. On the other hand, it is relatively simple to design and build the hardware for a crude weapon. The danger is real, therefore, that weapons-grade uranium or plutonium not under tight security could be stolen either by terrorists or by thieves who would profit from selling it to renegade countries.

In actuality, weapons-grade uranium does not have to pose much of a threat. Diluting the highly enriched uranium with uranium-238, the main constituent of natural uranium, to make economical reactor fuel is a straightfoward process. Subsequent reenrichment of the fuel for use in weapons is very unlikely because it demands sophisticated isotope separation techniques few countries have developed. Plutonium is another matter. All of its isotopes are fissile, so isotopic dilution does not render plutonium unusable for weapons.

Over the past few years, many different methods of disposing of plutonium have been proposed. They range from shooting it into the Sun with missiles, to deep-seabed disposal, to fissioning it within a new generation of nuclear reactors. The NAS report rejects most of the methods suggested so far, but does recommend pursuing two of the options. One is to incorporate the plutonium in mixed-oxide fuel, a mixture of plutonium and uranium oxides, and use it to fuel commercial nuclear reactors. The other is to mix the plutonium with high-level waste and molten glass and mold the resulting material into large glass logs for eventual geologic disposal.

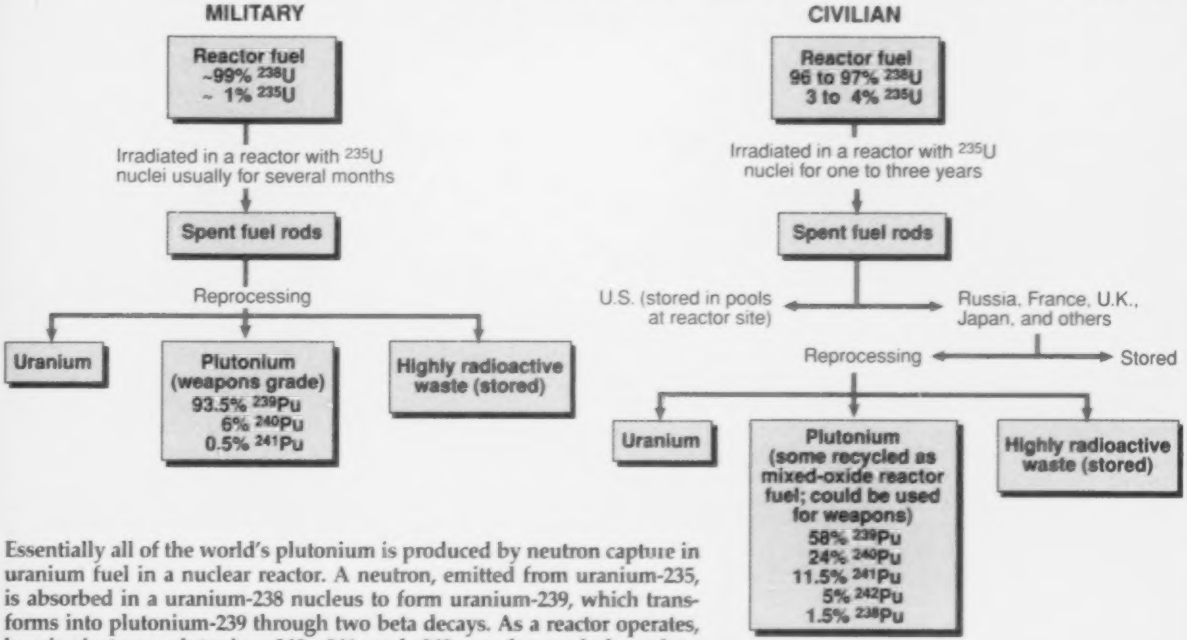
One troubling difficulty is that although the options for plutonium disposal recommended by the NAS report could work in the U.S., they may not only be unacceptable in Russia, but also unwise and unworkable given safety problems with its reactors and the breakdown in infrastructure.

Until recently, neither the U.S. nor Russia has had to seriously consider how they were going to safely store or dispose of large amounts of surplus plutonium. And so far, neither country is anywhere close to reaching a consensus on the issue, though the Clinton Administration is planning to make a decision by 1996.

Basically, the conflict is between those who believe plutonium will have no value in the near future and those who believe it has intrinsic energy value that can be exploited within a few decades. The latter group expects the plutonium will be useful as fuel for breeder reactors or some other kind of advanced nuclear reactor.

John H. Gibbons, director of the White House Office of Science & Technology Policy (OSTP), recently expressed the Ad-

Plutonium for military and civilian purposes is produced by essentially the same process


MILITARY
Reactor fuel
~99% ^{238}U
~ 1% ^{235}U
Irradiated in a reactor with ^{235}U nuclei usually for several months
Spent fuel rods
Reprocessing
Uranium
Plutonium (weapons grade)
93.5% ^{239}Pu
6% ^{240}Pu
0.5% ^{241}Pu
Highly radioactive waste (stored)
CIVILIAN
Reactor fuel
96 to 97% ^{238}U
3 to 4% ^{235}U
Irradiated in a reactor with ^{235}U nuclei for one to three years
Spent fuel rods
U.S. (stored in pools at reactor site)
Russia, France, U.K., Japan, and others
Reprocessing
Stored
Uranium
Plutonium (some recycled as mixed-oxide reactor fuel; could be used for weapons)
58% ^{239}Pu
24% ^{240}Pu
11.5% ^{241}Pu
5% ^{242}Pu
1.5% ^{238}Pu
Highly radioactive waste (stored)

Essentially all of the world's plutonium is produced by neutron capture in uranium fuel in a nuclear reactor. A neutron, emitted from uranium-235, is absorbed in a uranium-238 nucleus to form uranium-239, which transforms into plutonium-239 through two beta decays. As a reactor operates, heavier isotopes plutonium-240, -241, and -242 are also made by subsequent neutron capture. The longer the fuel stays in the reactor, the higher are the concentrations of heavier isotopes. If weapons-grade plutonium is being produced, the fuel is usually removed after a few months. If the reactor is being run primarily to produce power, the fuel is left in the reactor for up to a few years. In the U.S., waste from military reprocessing will be mixed with molten glass, made into glass logs, and eventually stored in a geologic repository. Spent fuel rods from civilian reactors will also be stored in a geologic repository after one is approved. In the countries that reprocess spent fuel from civilian reactors, part of the extracted plutonium is made into mixed-oxide fuel, a mixture of plutonium and uranium oxides.

ministration's view of how nuclear dismantlement should progress: "Our vision is of the U.S. and Russia running our nuclear weapons complexes in reverse—dismantling thousands of nuclear weapons rather than building more, getting rid of nuclear weapons materials rather than producing ever larger stockpiles, cleaning up rather than further fouling our nuclear sites, fostering openness and trust rather than maintaining strictest secrecy. This Administration is committed to making that vision a reality."

And it needs to do so soon. In the U.S., weapons are being dismantled at a rate of about 1,800 annually at the Department of Energy's (DOE's) Pantex plant near Amarillo, Tex. By 2003, up to 400 metric tons of highly enriched uranium and about 50 metric tons of plutonium will have been taken from weapons. In Russia, roughly the same number of weapons are being dismantled each year at four sites. Eventually, the Russians will remove more than 500 metric tons of highly enriched uranium and 50 to 100 metric tons of plutonium from their warheads.

Deteriorating safeguards

Experts agree that though security could be improved, plutonium and highly enriched uranium are being guarded reasonably well in the U.S. But in the former Soviet Union, where the political and economic situation is unstable and organized crime has skyrocketed, the risk of theft or diversion is high. The system of accounting for weapons and fissile materials was never sophisticated, but those materials were heavily guarded before the breakup of the Soviet Union. Now, workers at the nuclear storage and research facilities are paid infrequently or not at all. The temptation to accept bribes or to sell weapons-grade plutonium or highly enriched uranium is great. To compound the problem, substantial quantities of fissile materials are located in four former Soviet countries: Russia, Ukraine, Kazakhstan, and Belarus.

Already, three thefts of uranium, including one of weapons-grade material, have been confirmed in Russia. Also, according to Vladimir A. Orlov, a journalist with *Moscow News*, several plutonium thefts took place at Krasnoyarsk-26, a formerly secret city near Krasnoyarsk in Siberia, but the thieves were caught. In addition, organized crime is spreading across Europe from Italy into Russia, and many people fear it may soon get into the business of smuggling plutonium and enriched uranium from Russia. First deputy minister of the interior Mikhail Yegorov says there are nearly 5,700 criminal groups in Russia with a total of about 100,000 members and connections in 29 countries. Yegorov's agency investigated nine alleged thefts of fissile weapons materials during the past 18 months. The U.S. Federal

Nuclear weapons can be made from reactor-grade plutonium

In its report, "The Management and Disposition of Excess Weapons Plutonium," a National Academy of Sciences (NAS) panel states that nuclear bombs can be made from spent fuel from ordinary nuclear power plants.

That statement directly contradicts the nuclear power industry's longstanding assertion that bombs could not be made from its spent fuel. In fact, just recently, the Japanese government-owned utility, the Power Reactor & Nuclear Fuel Development Corp., made this assertion in a promotional video it distributed to reassure citizens living near the Monju breeder reactor, which started operating in April.

Some nuclear power advocates admit that nuclear weapons could be manufactured with reactor plutonium. The U.S. government did, after all, build and test a bomb made of commercial reactor-grade plutonium in 1962. However, advocates claim that since no country has actually chosen to do so, reactor plutonium is not strategically important.

According to the NAS panel, bombs made from reactor plutonium, while somewhat less efficient and less reliable than those made of the weapons-grade material, can still be highly destructive. If a reactor is used to produce plutonium for weapons, fuel rods are removed from the reactor early in the radiation cycle, when the ratio of plutonium produced from uranium-238 absorption of a neutron and decay to plutonium is about 93% plutonium-239 to about 6% plutonium-240. If a reactor is used for power production, the fuel rods are left in the reactor much longer to extract more of their energy potential and larger amounts of the higher isotopes of plutonium are created. Typically, when the spent fuel is removed, about 58% of the plutonium is plutonium-239, 24% is plutonium-240, and the rest is mostly plutonium-241 and americium-241.

As a nuclear weapon is detonated, the plutonium is compressed using chemical explosives and, at a precise moment, a burst of neutrons is generated to set off a chain reaction. However, if the plutonium used to make a bomb is contaminated with higher than normal percentages of plutonium-240 or -242, the spontaneous neutrons they emit have a high probability of setting off the chain reaction a fraction of a second too early, reducing the bomb's yield.

But even if preinitiation occurs at the worst possible moment, a simple bomb made of reactor-grade plutonium would have a yield of one to a few kilotons, enough to cause at least one third of the destruction wrought by the Hiroshima weapon, says Brian G. Chow, senior physical scientist at Rand Corp., Santa Monica, Calif.

Another drawback of reactor-grade plutonium is that it is too hot. It generates six to 10 times more heat per kilogram than does weapons-grade plutonium. So a bomb made of reactor plutonium would have to be constructed in such a way that heat is conducted away from the plutonium while the bomb is in storage, or it would need to be assembled only shortly before use.

Since weapons can be made of reactor plutonium, the NAS panel recommends that the "U.S. pursue new international arrangements to improve safeguards and physical security over all forms of plutonium [including that in spent fuel] and highly enriched uranium worldwide."

All forms of plutonium should eventually be placed under International Atomic Energy Agency safeguards, says John P. Holdren, chairman of the Committee on International Security & Arms Control that conducted the NAS study and professor of energy at the University of California, Berkeley. "The adequacy of protection and safeguards for separated civilian plutonium deserve a searching review," he says.

Bureau of Investigation will soon open a Moscow office to work with the Russians on preventing thefts of nuclear weapons and materials.

"Every day that goes by, every weakening of the basic custodial and control arrangements in the former Soviet Union adds risks that fissile materials may be stolen and wind up in the hands of potential proliferators," says Catherine M. Kelleher, senior fellow in the foreign policy studies program at the Brookings Institution in Washington, D.C.

Wolfgang K. H. Panofsky, professor and director emeritus of the Stanford Linear Accelerator Center, Stanford University, and chairman of the panel that wrote the NAS study, echoes her view: "Any day now, we could wake up and read in the morning newspaper that enough material for a dozen bombs really has been stolen. . . . On our last visit to Russia a couple of months ago, we were told universally that their safeguarding of nuclear materials had deteriorated. But we still don't have a very good way to quantify that."

Since an economical fuel can be made from uranium removed from weapons, almost no one suggests it be put into irretrievable storage or made into a form that can't eventually be used to power nuclear reactors. The U.S. has contracted to purchase 550 metric tons of highly enriched uranium from the Russians for $12 billion over the next 20 years.

Unlike uranium, plutonium does not have current economic value for generating electricity. Twenty years ago, most experts believed this radioactive, synthetic element could eventually be substituted for uranium-235 in conventional nuclear reactor fuel and put into mixed-oxide fuel. This mixture, they thought, would be an economical fuel for nuclear reactors. At the time, nuclear power was expected to expand rapidly, and uranium was predicted to be in short supply soon. Now, many more sources of uranium have been discovered and nuclear power's expansion has slowed.

Today, even if the plutonium is free, mixed-oxide fuel costs $500 per kg more than conventional uranium fuel, which costs about $1,000 per kg. This extra cost makes electricity generated with mixed-oxide fuel more expensive. And most experts believe it will not be an economical fuel for many decades. "We are talking basically about a half century" before plutonium becomes competitive, says Panofsky.

Recommended disposal methods

The panel that wrote the NAS study is a standing committee called the Committee on International Security & Arms Control. It suggests steps that should be taken now to guard supplies of plutonium removed from weapons. One step is bilateral U.S.-Russian monitoring of warhead dismantlement. Others include setting up secure interim storage for the fissile materials and establishing an international monitoring system to verify the stockpiles and ensure that materials are not withdrawn for use in new weapons. The panel also urges Russia to stop producing fissile weapon materials and both countries to commit a very large fraction of their plutonium and highly enriched uranium from dismantled weapons to nonaggressive uses. The U.S. and Russia have already made initial moves to accomplish these goals but have not fully implemented any of them.

After these steps are taken, the NAS committee recommends that plutonium be disposed of by one of its two suggested options. If plutonium is made into mixed-oxide fuel, it should be burned in one or several reactors that are owned or controlled by governments. These could be light-water reactors in the U.S. and Russia, or heavy-water-moderated reactors in Canada. In the process, about 30% of the plutonium would be destroyed and the rest embedded in spent fuel. In that form, it would be far less accessible as a source of weapons material than are the hollow metal-clad plutonium spheres—pits—contained in weapons that are now being stored in the U.S. Once the project has begun, burning plutonium as mixed-oxide fuel would cost the U.S. government from one to several billion dollars over 10 years, but that amount is reasonable considering the danger these stockpiles pose, Panofsky says.

The other option, mixing weapons plutonium with high-level nuclear waste and molten glass and molding this mixture into 2-metric-ton stainless-steel-clad glass logs, would probably cost less than burning plutonium as mixed-oxide fuel, says Richard L. Garwin, IBM fellow emeritus at Thomas J. Watson Research Center in Yorktown Heights, N.Y. The glass log option is attractive in some ways because it is only a minor modification of what DOE intends to do anyway. The agency will soon be mixing high-level waste from weapons production with molten borosilicate glass and molding this into logs at its Savannah River facility. If the glass log option is used, the plutonium would be put in along with the waste.

Although spent fuel and the logs would contain plutonium, thieves would be less likely to steal them because they would be heavy and so radioactive as to require remote handling. A person cannot stand a few feet from fresh spent fuel or a log for more than a few minutes without danger of serious injury. Both the spent fuel from burning plutonium in mixed-oxide fuel and the glass logs would eventually be disposed of in a geologic repository. However, neither disposition option could begin to make a dent in the nuclear stockpile in less than a decade, so plutonium pits would still have to be guarded carefully for many years to come.

The panel also mentions a third option, which it says may be "comparably attractive": burying the plutonium in 4-km-deep boreholes sealed with bentonite clay and concrete. Plutonium in a borehole would be very inaccessible to would-be weapons makers, but it could be recovered at a later time by the state.

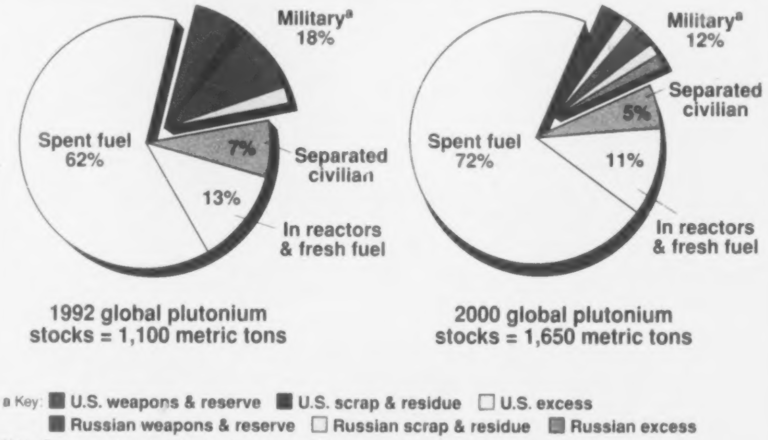
Taken together, these immediate and intermediate steps to secure plutonium would guard against three contingencies in the former Soviet Union—breakup, breakdown, and breakout, Panofsky says. He defines breakup as the creation of several nuclear armed states where previously there was only one, breakdown as the erosion of control over nuclear materials, and breakout as the repudiation of arms reduction agreements and rebuilding of a large nuclear arsenal.

Unlike many previous NAS studies, this one on plutonium disposition is strongly influencing U.S. policy. The panel's proposals now form the foundation of the Administration's thinking on the issue. However, the situation is still fluid, and a different disposition path than any of those recommended by NAS may eventually be chosen. "We are examining a variety of other disposition options as well," says Gibbons.

Harold A. Feiveson, a research scholar at Princeton University, offers another such disposition option, a compromise between those who want to save plutonium for a new generation of reactors, as the Russians do, and those who want to make it inaccessible in the near future—the U.S. position. He suggests that the Russians mix plutonium in their pits with molten glass and mold this into 2-metric-ton logs. These could be stored indefinitely. They would not be highly radioactive, but they would be a lot harder to steal than a pit, which contains on average 3 to 4 kg of plutonium.

The Russians might be inclined to accept this idea because it would allow them to extract the plutonium at a future time for use in reactors. Another possibility is to blend plutonium into a uranium dioxide-based matrix obtained by exposing spent fuel to high-temperature oxidation-reduction cycles, say Feiveson and Ed Lyman, a research

Military uses account for small and declining fraction of world plutonium stocks



Note: The amount of plutonium in the weapons of the other nuclear states is very small and is not included.
Source: C&EN estimates based on data from National Academy of Sciences Committee on International Security & Arms Control

physicist, also at Princeton. This would produce dirty (radioactive) mixed-oxide fuel rods that could be stored and, in principle, used later directly in reactors.

Others have suggested that the U.S. purchase the Russian pits just as it is paying $12 billion for Russian highly enriched uranium. "I believe that even though plutonium has negative value to the civil sector," says IBM's Garwin, "it would be worthwhile for the U.S. to buy the weapons plutonium from the Russians at the same price we are paying for highly enriched uranium."

NAS disposal criteria

The NAS panel used several criteria in assessing possible plutonium disposal options: timeliness of implementation, safety, cost, and inaccessibility. First, the panel decided an option should require little or no technological development before it is implemented. Burning plutonium as mixed-oxide fuel meets this criterion fully. Such fuel is being produced at a facility in Belgium, and it has been used successfully to generate electricity in several types of conventional light-water reactors. The glass log option would require a few years of research before it could be implemented.

Worldwide, civilian stocks of plutonium are several times larger than military stocks and growing much faster, by some 60 to 70 metric tons each year. About 80 to 90 metric tons of civilian reactor-grade plutonium is now stored in separated form in various countries, and about 600 metric tons of plutonium is contained in the spent fuel from civilian power reactors. Therefore, the NAS panel concluded that the preferred options should meet what it calls the "spent fuel standard"—making the plutonium from dismantled weapons only as difficult to extract and steal as the plutonium in civilian spent fuel.

The mixed-oxide fuel option would destroy about 30% of the weapons plutonium and embed the rest in spent fuel; the glass log option would not destroy the plutonium but it would make it as difficult to retrieve as is the plutonium in spent fuel.

In addition, the NAS committee wants the plutonium to be disposed of in a way that does not disperse it widely in society. For this reason, it rejects the idea of burning the plutonium as mixed-oxide fuel in a large number of commercial power reactors scattered across the U.S. and Russia. This would provide too many opportunities for theft. "It is important to use only a few reactors and that they be government-owned" to avoid proliferation risks, comments John P. Holdren, chairman of the NAS committee and professor of energy at the University of California, Berkeley.

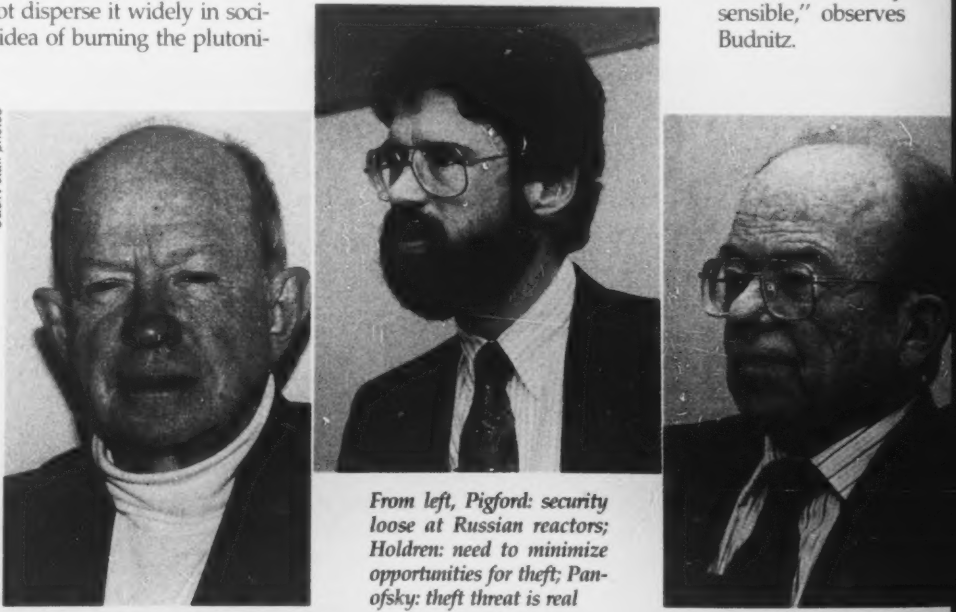
The deep-borehole option meets most of the panel's criteria except for inaccessibility and, to some degree, development time. The panel believes, however, that since the public has not yet accepted geologic repositories for spent fuel or high-level waste, it would be very reluctant to accept deep-borehole disposal. Also, the borehole method would require further study to determine the risk of plutonium or its decay products being released from the borehole into the environment at some future time.

Technological development

The NAS panel recommends that a choice of disposition options not be made immediately because some technical questions concerning the glass log option need to be answered first. "In the path toward final disposition, there are some very challenging chemical and chemical engineering problems. Those problems that remain to be solved are an important reason why we can't make a technical decision today," says Robert J. Budnitz, president of Future Resources Associates in Berkeley, Calif., and a former member of the Nuclear Regulatory Commission (NRC).

First, scientists do not know what percent of plutonium can be put into glass without causing a criticality problem (a chain reaction) in the melter. Most experiments on glass logs at DOE's Savannah River plant have been done with high-level radioactive waste alone, not with waste plus plutonium.

Plutonium causes concern because it tends to form pockets of locally concentrated material in glass, says Thomas H. Pigford, professor of nuclear engineering at the University of California, Berkeley, and a member—along with Budnitz—of an NAS panel on reactor-related options for the disposition of excess weapons plutonium. "That has been the cause of some nuclear criticality events at Los Alamos," he explains. If it turns out that the glass logs can contain only 1% plutonium, then that option becomes too expensive because of the large number of logs that would have to be made and stored. For the glass log method to be viable, a plutonium content of 3 to 7% would be required. "I couldn't tell you whether we can put enough plutonium in the glass to make vitrification actually sensible," observes Budnitz.



C&EN staff photos

From left, Pigford: security loose at Russian reactors; Holdren: need to minimize opportunities for theft; Panofsky: theft threat is real

The highly enriched uranium deal is only a partial solution

The U.S. deal to buy surplus, highly enriched uranium from Russia is only a partial solution to the problem of uranium proliferation. As part of the deal, the Russians will dilute 550 metric tons of the highly enriched uranium from their dismantled weapons (more than 90% uranium-235) with uranium from ore (mostly uranium-238) so it contains 4.4% uranium-235. The U.S. will purchase the diluted uranium over a period of 20 years for $12 billion. The deal's objectives are to assist the Russian economy, help fund Russia's disarmament, and ensure that the once highly enriched uranium is virtually useless for weapons.

Despite these advantages, the arrangement has several pitfalls. First, the U.S. does not know what fraction of Russia's total stock of highly enriched uranium it is purchasing. The Russian Minister of Atomic Energy, Viktor N. Mikhailov, said recently that Russia had produced 1,250 metric tons. Other Russians say the actual production was 900 metric tons and allege that Mikhailov doesn't know what he is talking about. Oleg Bukharin, a Russian scientist working at Princeton University, calls the amount of highly enriched uranium in Russia "the greatest mystery." But, he says, "My sense is that the 550 metric tons the U.S is buying is most of the surplus."

Furthermore, according to Thomas B. Cochran, senior scientist at the Natural Resources Defense Council, in Washington, D.C., "The protocol worked out by the Administration may permit the U.S. to confirm that the uranium is highly enriched uranium, but it aparently does not permit the U.S. to confirm that the highly enriched uranium actually is [coming] from dismantled weapons."

Another problem is that Russia will sell only a relatively small fraction—about 50 metric tons—of its highly enriched uranium to the U.S. during the next five years. So the bulk of the uranium could remain in Russia in undiluted form for years. During this time, it could present even more of a proliferation risk than plutonium.

It is easier to make a uranium-235 bomb than a plutonium bomb because a simple, gun-assembly design like that used in the Hiroshima weapon (which was not tested before it was used) can be employed. In this type of bomb, two subcritical masses of highly enriched uranium are propelled together with a conventional explosive, producing a supercritical mass—a mass that is more than large enough to sustain a chain reaction.

In contrast, plutonium requires the more complicated implosion technique, which uses a peripheral charge of chemical high explosive to compress the metal. "Plutonium is so tricky, it requires a lot more finesse," says Thomas H. Pigford, professor of nuclear engineering at the University of California, Berkeley, and a member of the National Academy of Sciences panel on reactor-related options for the disposition of excess weapons plutonium.

The situation is much the same in the U.S. There isn't much of an economic incentive for the U.S. to blend down its own supply of weapons uranium for use in power reactors; there isn't any market. And currently, a worldwide uranium glut exists owing to the nuclear power industry's snail-like expansion.

Thus, a lot of unblended, highly enriched uranium that could possibly be stolen by terrorists could also remain in the U.S. for many years. However, the proliferation problem could be solved fairly quickly, if the two governments decide to act. All they would have to do is blend down all the weapons uranium to a ^{235}U enrichment level of 20% or less—a level unsuitable for weapons.

Also, researchers need to determine how glass logs would age in a geologic repository. Over a short time in geologic terms, the boron in the borosilicate glass would act as a neutron absorber. But over perhaps 20,000 to 100,000 years, the boron might leach out preferentially because it is more soluble in water than plutonium, Pigford says, so in some future era, there is a chance the plutonium in the log would become critical.

Budnitz estimates it would take four to six years of research to answer the technical questions about glass logs. "Nevertheless, there is a huge enthusiasm for vitrification in some quarters, because rather rapidly and without using reactors it could dispose of plutonium," he says.

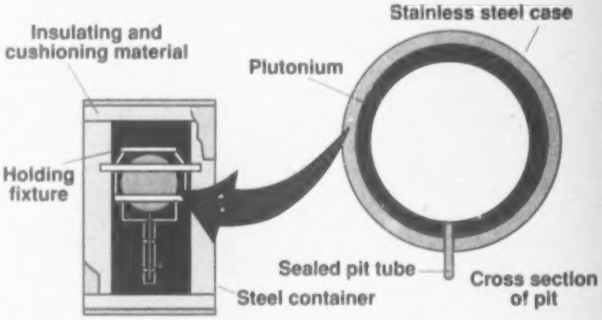
Using the plutonium as mixed-oxide fuel in reactors would require no further research. Some reactors are more suited to burning such fuel than others, however. Most of the existing light-water reactors in the U.S. could not burn a full core of mixed-oxide fuel. Two thirds of the core would have to be conventional uranium fuel unless the reactors were modified with more control rods. There are few U.S. reactors, other than three System-80 light-water reactors at the Palo Verde site in Arizona, that could operate with full mixed-oxide fuel cores without modification.

In Russia, only the VVER-1000 light-water reactors would be safe enough, with some modifications, to burn mixed-oxide fuel. Several VVER-1000s still under construction could be completed in such a way that they could handle full cores.

Technologically, the most inherently suitable type of reactor for burning such fuel is the Canadian deuterium-uranium reactor (CANDU), which is moderated by heavy water and was originally designed with extra neutron control absorbers for the possible future use of plutonium. Consequently, these reactors can handle a full mixed-oxide core with no modification. "Of all the reactor-related options, to me, CANDU is the most attractive," Pigford says. Canada, however, has a long-standing policy against using fuels other than natural uranium in its power reactors. So it is a question of whether Canada could be convinced to contribute to disarmament by burning U.S. or Russian plutonium.

Even some experts who favor burning plutonium in U.S. light-water reactors have misgivings about using the same disposal method in Russia. Because Russian control over its nuclear materials seems to be deteriorating, they worry that plutonium removed from weapons might be stolen as it is being transported to one or several sites to be made into fuel, and they are also concerned about it being stolen from reactor sites.

Plutonium from U.S. weapons is contained,



Following removal from a nuclear weapon, the hollow stainless-steel-clad spherical component containing on average 3 to 4 kg of plutonium, commonly referred to as the pit, is placed inside a holding fixture. This holding fixture rests inside a steel container that is insulated and cushioned with a material made largely of cellulose. The assembly is then stored inside a bunker at the Department of Energy's Pantex plant near Amarillo, Tex. (at right).

In addition, they worry about safety problems at even the safest of Russia's light-water reactors, the VVER-1000s, which do not fully meet Western safety standards. For example, with U.S. reactors, two independent supplies of electricity are required so if one fails, the other does not. Russian reactors often have something that looks like two independent systems, but when examined in detail, it turns out they are interconnected. "If one fails, the other one fails," Pigford says.

Management concerns are also an issue. A well-designed, well-built reactor can be run in an unsafe manner. "Recently, I walked into one of [Russia's] nuclear power plants north of Moscow, and it was like going into a supermarket," Pigford recalls. "You go in through a turnstile and there is no careful determination of who you are." Only a handful of people were guarding the reactor in contrast to U.S. plants, which typically have a security force of about 100 people. Management is an issue with glass logs, as well. "Russia has been very careless in its management of environmental controls in reprocessing. Unless they change their ways, I wouldn't want them to go into glassmaking," Pigford says.

Some experts are also concerned that if Russia were to burn weapons-grade plutonium in its light-water reactors, there would be no way to prevent it from reprocessing the spent fuel. Russia currently reprocesses part of the spent fuel from its power reactors.

Because of these concerns, several observers who favor burning plutonium in U.S. reactors say they are opposed to Russia's burning plutonium in its reactors. "There is probably only one thing worse than storing pits in Russia [that are] right now under lock and key," says a Pentagon official, "and that is throwing the pits into oxide production and fuel fabrication and then ultimately reprocessing. We won't be able to control Russian reprocessing. That would just increase [nuclear] proliferation risk, not decrease it."

Advanced reactors suggested

Many engineers at DOE and at several companies that build nuclear reactors are advocating development of advanced reactors for burning weapons-derived plutonium. Basically, they propose using one of four types: advanced light-water reactors, modular high-temperature gas-cooled reactors, advanced liquid-metal reactors (essentially advanced breeders), and accelerator-based conversion.

Of these, the advanced light-water reactor is the closest to commercialization. One such design, the System-80$^+$ reactor developed by ABB-Combustion Engineering, burns a full core of mixed-oxide fuel. It has more safety features than existing light-water reactors, and NRC is well along in reviewing its design. Although this reactor may be safer than existing light-water models, it would not process plutonium any faster per unit of power produced than current reactors.

The modular high-temperature gas-cooled reactor is cooled by high-temperature helium and moderated with graphite blocks in the core. It is fueled with tiny pellets of plutonium or highly enriched uranium that are coated with several layers of protective materials, bonded into fuel rods, and placed in the graphite blocks. The reactor can potentially destroy up to 80% of the plutonium in the fuel.

DOE concludes in its 1993 report, "Plutonium Disposition Study," however, that this reactor is the least cost-effective of the five reactors it evaluated. But the manufacturer, General Atomics, says the reactor is actually much more economical than DOE calculates. General Atomics has signed an agreement with the Russian Ministry of Atomic Energy (MINATOM) to develop this reactor jointly for burning Russian weapons plutonium if the U.S. government funds its project.

A number of countries are developing advanced liquid-metal reactors, which recycle and reprocess plutonium. U.S. designs employ a pyroprocessing approach that reduces costs and wastes from reprocessing and never fully separates the plutonium in a form that can be used for nuclear weapons. If plutonium were repeatedly recycled through the reactor, most of it could be fissioned. A more practical approach would be to burn the weapons plutonium in a once-through mode and thus transform it into spent fuel. The capital cost of the advanced liquid-metal reactor is higher than that of light-water models, and the NRC licensing process for it has not advanced very far.

DOE engineers have been developing the accelerator-based conversion reactor both as a means of disposing of weapons plutonium and of fissioning actinides (transuranic elements) and fission prod-

Johnson: Pantex facility is simple, sound

then placed in bunkers

ucts to reduce the long-term radioactivity of high-level waste.

The neutrons in the accelerator-based conversion system, which are produced by a beam of particles from an accelerator hitting a target, cannot sustain a chain reaction without outside input. This is a safety advantage because the reactor can be shut down instantaneously by turning off the power to the outside neutron source. The fuel is fluid and continuously fed out of the reactor, reprocessed to remove fission products, and fed back in. In the process, plutonium is almost totally destroyed.

Some DOE experts say this reactor would be especially beneficial because it would destroy the plutonium almost completely and reduce the radioactivity of the resulting waste below what it would be with other methods. For example, Edward D. Arthur, project leader for accelerator systems at Los Alamos National Laboratory, claims that accelerator-based conversion could "reduce the long-term toxicity of existing defense wastes destined for a geologic repository." As a result, more waste could be stored in the proposed Yucca Mountain repository in Nevada, he says.

So far accelerator-based conversion exists only on paper, and many technological hurdles remain before this system could be used. But Arthur believes a full-scale demonstration plant could be finished in 15 years. In contrast, Pigford says, accelerator-based conversion could not be developed to destroy plutonium for decades. In its report on this subject released last December, the General Accounting Office agrees with Pigford. It concludes that practical application of this system "is at least decades away, and a number of constraints could slow or prevent application should it be actively pursued. . . . The research necessary to prove that these concepts are technically and economically feasible has not been done."

Pigford also says that reducing the radioactivity of the waste to be stored potentially at Yucca Mountain may not be a real advantage for two reasons. Yucca Mountain's capacity was a political decision, not a technological one, and four or five times as much waste could be stored there, even without decreasing its radioactivity. Furthermore, Pigford says, reducing heat in high-level waste by lowering its radioactivity could create a problem. Right now, waste to be stored in Yucca Mountain would be so hot it would keep any water in its vicinity in vapor form. If the temperature of the waste is reduced, water could remain in liquid form and cause more corrosion.

Many scientists and engineers see the need to dispose of weapons-derived plutonium as a way to increase government funding for the advanced reactors they have been working on. They think that such increased funding would eventually revitalize the nuclear power industry in the U.S. But Panofsky says: "U.S. interests would be served well if one could unlink the decision about the plutonium question from the nuclear power future as much as possible." He and many other nuclear experts also argue that plutonium from weapons is not needed for advanced reactors. If they are developed someday, these reactors could initially be fueled with reprocessed reactor plutonium. It would take a minimum of two decades to develop and license any type of advanced reactor, Panofsky predicts.

The NAS panel therefore rejects the idea of using advanced reactors for burning plutonium. "Advanced reactors should not be specifically developed or built for transforming weapons plutonium into spent fuel, because that aim can be achieved more rapidly, less expensively, and more surely using existing or evolutionary reactor types," Panofsky says.

In line with that reasoning, the Clinton Administration has proposed sharply reduced spending for development of all types of advanced reactors, except for advanced light-water models. In fiscal 1995, funding for the total nuclear energy program at DOE would fall from $343 million to $248 million.

Plutonium's risks to human health depend on its form

In a nuclear explosion, plutonium-239 fissions and releases a huge amount of energy and radiation. But plutonium itself is a highly toxic element that requires a great deal of care in handling.

Experts agree that the silvery, unstable metal plutonium-239, with a half-life of 24,000 years, is hazardous and should be isolated from the biosphere. However, the risks posed to workers and communities by stored plutonium depend on the route of exposure as well as the particle size, isotope, and chemical form.

Weapons-grade plutonium outside the body presents little risk unless exposures are frequent and extensive. It emits primarily alpha particles, which cannot penetrate skin, clothing, or even paper. Nearly all the energy from plutonium is deposited on the outer, nonliving layer of the skin, where it causes no damage. The neutrons and the relatively weak gamma photons it emits can penetrate the body, but large amounts of weapons-grade plutonium would be needed to yield substantial doses.

Workers wearing only lead aprons can handle steel drums containing solid plutonium metal with no immediate untoward effects. However, as weapons-grade plutonium ages, it becomes more dangerous because some of the plutonium-241 it is contaminated with is converted via beta decay to americium-241, which emits far stronger gamma radiation.

On the other hand, plutonium inside the body is highly toxic. Solid plutonium metal is neither easily dispersed nor easily inhaled or absorbed into the body. But if plutonium metal is exposed to air to any degree, it slowly oxidizes to plutonium oxide (PuO_2), which is a powdery, much more dispersible substance. Depending on the particle size, plutonium-239 oxide may lodge deep in the alveoli of the lung where it has a biological half-life of 500 days, and alpha particles from the oxide can cause cancer. Also, fractions of the inhaled plutonium oxide can slowly dissolve, enter the bloodstream, and end up primarily in bone or liver.

Plutonium oxide is weakly soluble in water. If it is ingested in food or water, only a small fraction (4 parts per 10,000) is absorbed into the gastrointestinal tract. However, it may take just a few millionths of a gram to cause cancer over time. In animals, small doses induce cancer, especially in lung and bone.

In published studies of plutonium's effects on humans, most subjects were exposed to multiple sources of radiation. Some researchers say the available health data on plutonium workers have not yet been used to do careful epidemiological studies, because researchers have been denied access to much of the data on workers and military personnel exposed to plutonium. In any event, in the studies done thus far, plutonium workers do not show major excesses of any type of cancer.

Because of the relative lack of human data, the risks from chronic exposure to plutonium are uncertain. Exposure standards in the U.S. are based partly on studies of survivors of Hiroshima and Nagasaki and partly on animal experiments. A 1991 White House Office of Science & Technology Policy study says that "sufficient human data are not available to provide accurate risk assessment of exposure."

Despite evidence of plutonium's toxicity, the Japanese government-owned Power Reactor & Nuclear Fuel Development Corp. (PNC) distributed a video this year that portrays plutonium as harmless. The video was designed to reassure people living near the newly opened Monju breeder reactor, which is fueled with a mixture of plutonium and uranium oxides.

The cartoon features a captivating character called Pluto Boy, a small child with a green cap marked "Pu." Pluto Boy says there is no evidence plutonium causes cancer. "Even if you drink plutonium in your water," he explains, "it won't be absorbed by your stomach and it will be flushed out of your body. . . . It is unthinkable that I could cause any adverse effects in the body."

In February, Energy Secretary Hazel O'Leary wrote to PNC, protesting the misleading information presented in the video, and the Japanese media criticized it strongly as well. PNC had already distributed 200 copies of the video to local Japanese authorities, but subsequently promised not to send out any more copies.

However, Sen. J. Bennett Johnston (D.-La.), chairman of the Committee on Energy & Natural Resources and the Appropriations Subcommittee on Energy & Water Development, wants to continue funding the advanced liquid-metal reactor and the modular high-temperature gas-cooled reactor, because "both technologies could consume weapons plutonium more completely than a light-water reactor." He believes the U.S. should consider other policy areas, such as the future need for advanced reactors for electricity generation, when choosing a method of disposing of plutonium. Advanced reactor research may be saved, at least for 1995.

Russian breeder reactors

Analogous to the DOE engineers who want to burn plutonium in advanced reactors are the nuclear experts at Russia's MINATOM who want to burn plutonium in breeder reactors. This group wants to preserve the pits for use in breeder reactors after the government has finished building several large ones. For example, Russian Minister of Atomic Energy Viktor N. Mikhailov predicts, "Fast [breeder] reactors will be ready for large-scale plutonium utilization at the beginning of the next century." And he concludes that "any short-term plutonium management program must be based on safe and reliable storage of weapons plutonium until it can be used in [breeder] reactors." In general, other Russian officials at MINATOM agree with Mikhailov. They say plutonium is a national treasure that should not be mixed with high-level waste. Also, they are adamantly opposed to incorporating the plutonium in mixed-oxide fuel and burning it in ordinary light-water reactors.

Currently, Russia has only one commercial-sized breeder reactor, the BN-600 in Beloyarsk in the Urals, which has been plagued with safety and operating problems. Russia has started site preparation for one large breeder and has drawn up plans for three others, all to be BN-800s and to be built near Chelyabinsk in the Urals. But Russia does not have the funds to finish them, so the only way it could acquire more breeder reactors in the near future is with heavy subsidies from some other country. It would take 20 to 30 years to build enough breeder reactors in Russia to begin to make a dent in its weapons plutonium, says NAS committtee chairman Holdren.

On the other hand, Richard Wilson, professor of physics at Harvard University, says Russia's schedule for completion of four BN-800 breeder reactors near Chelyabinsk by 2017 may be possible "if we do not confuse matters by insisting to the Russian government that it is a bad idea." Keeping the plutonium secure at Chelyabinsk "is surely easier than keeping it on the tips of thousands of warheads," he adds.

Problems with breeders

The promise of breeder reactors is a significant extension in the life of uranium resources. They permit the gradual replacement of uranium-238 by plutonium-239, which then can fission. But there are several reasons why many nuclear experts outside Russia do not look favorably on the idea of burning weapons-derived plutonium in breeders. One is that it will take several decades before the technology is sufficiently advanced to burn plutonium on a large scale. Another is that under normal operating conditions, the amount of plutonium in the spent fuel from breeders is even greater than in the initial fuel, and the plutonium in the blanket (the uranium-238 surrounding the fuel core) of a breeder is almost ideal weapons grade. Consequently, after burning plutonium in breeders, a nation would have more plutonium than it started with, and there could be a great incentive for terrorist groups to divert the plutonium in the blanket to produce weapons.

Breeder reactors can be modified to produce less plutonium than they are fueled with—in those cases they are called burners. But then, what is usually thought to be their great advantage—creating more fuel in the process of producing electricity—is eliminated. And, "if you redesign the reactor so it doesn't make more plutonium than it is fueled with, you raise new safety issues that have not been adequately resolved," Pigford says.

In addition, most of the breeder reactors built thus far around the world have been plagued with safety problems. Cracks often develop in the heat exchangers and in other parts, and argon gas bubbles passing through the core can cause problems. They contain thousands of tons of circulating sodium and water and large numbers of pipes and valves. Because sodium ignites spontaneously when it contacts water, this system can be safe only if it is entirely leak-proof.

As a consequence of breeder reactors' expense and unreliability, very few Western countries are now interested in developing them. Britain and Germany abandoned research on breeders in 1992, and President Bill Clinton announced last February that the U.S. would no longer fund breeder development. Japan and Russia are the only industrial countries that are actively trying to develop breeder reactor programs.

Storage issues

No one disputes the idea that plutonium pits should be stored securely to eliminate risk of theft or of environmental contamination of the surrounding community. But observers in both the U.S. and Russia see problems with the way their pits currently are stored, and local citizens in both countries who live near storage sites do not want the problems solved by having a permanent, more sophisticated site for pit storage built in their communities.

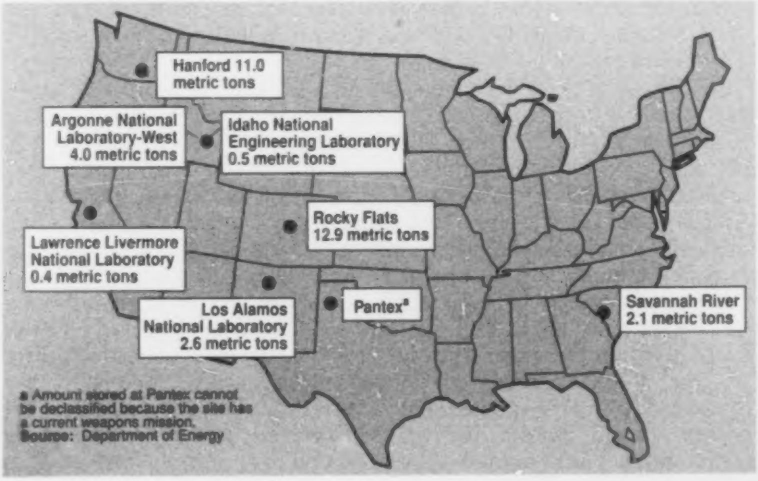
Russian pits are now being kept in warehouses at four sites at Tomsk-7, a formerly secret city near Tomsk, Siberia, and at Chelyabinsk-65, where weapons are being dismantled. Even the Russians admit these storage facilities are unsafe and liable to theft. The facilities do not protect against aircraft crashes, and they do not have an accountancy system even as simple as bar codes to mark the pit containers to enable inspectors to know whether any are missing. Also, they lack portal monitors that record automatically when radioactive materials enter or leave the storage facility. Such monitors were installed on DOE facilities in 1985.

The Pentagon has offered the Russians $30 million to help them establish a better system for accountancy and monitoring, but so far they have not accepted help in this area.

"DOE has developed a lot of systems for material control and accounting," says undersecretary of energy Charles B. Curtis. "The problem is getting Russia to apply these regimes. A team has been in Russia recently trying to do this," he says.

At a cost of $40 million, the U.S. has designed and built about 33,000 safe storage containers for Russian pits, and this summer it will start sending the containers. The U.S. is also providing $90 million for the Russians to design and build a modern underground storage facility for their pits.

Substantial quantities of weapons-grade plutonium are stored at various Department of Energy sites


Hanford 11.0 metric tons
Argonne National Laboratory-West 4.0 metric tons
Idaho National Engineering Laboratory 0.5 metric tons
Rocky Flats 12.9 metric tons
Lawrence Livermore National Laboratory 0.4 metric tons
Los Alamos National Laboratory 2.6 metric tons
Pantex[a]
Savannah River 2.1 metric tons

a Amount stored at Pantex cannot be declassified because the site has a current weapons mission.
Source: Department of Energy

The Isaiah project—privatizing plutonium disposal

A consortium of private companies has put forward a proposal for a government-private partnership to use weapons-grade plutonium as mixed-oxide fuel in light-water reactors. Three firms—Battelle Memorial Institute, Newport News Shipbuilding Corp., and Science Applications International Corp.—would acquire two partially completed reactors in Washington State, finish them at their own expense with private financing, and transfer ownership to the U.S. government. They would then operate the reactors to "burn" weapons-grade plutonium and generate electricity. The plan is known as the Isaiah project.

Revenues from the sale of electricity would allow the consortium to repay its debt from finishing the reactors. The government would pay for reactor operations and for fuel fabrication, storage, and disposal. The spent fuel would be stored on the Hanford site until it could be disposed of in a geologic repository.

A Department of Energy facility, built on the Hanford Reservation but never used to produce fuel for the former U.S. breeder program, would make the mixed-oxide fuel for the project. The nuclear reactors proposed for use are Washington Nuclear Project-1 (WNP-1), which is 63% complete and located on the Hanford site, and WNP-3, which is 75% complete and located in Satsop in western Washington. WNP-3 is a System-80 reactor that would not require modification to use a full core of mixed-oxide fuel. WNP-1 would have to be modified.

The project has several advantages. It would gainfully employ two unused reactors. It would confine plutonium burning to two sites, and it would reduce up-front U.S. government costs for plutonium disposal. It would also mean that plutonium burning would be managed by the private sector, which some see as an advantage. WNP-1 and WNP-3 were started at a time when nuclear power was expected to expand rapidly; they were mothballed when the owner decided that power from these reactors would not be needed.

"The Isaiah project could tip the balance in favor of burning mixed-oxide fuel in reactors because it is a convenient institutional arrangement," says Robert J. Budnitz, president of Future Resources Associates in Berkeley, Calif. However, if the Clinton Administration waits until 1996 to make a decision on plutonium disposition, as it plans to do, two of the leading light-water reactor options—WNP-1 and WNP-3—may no longer be available. Their current owner plans to begin dismantling them early next year.

The new facility will have temperature control, modern alarms, a fire-control system, and will provide protection against aircraft crashes.

The Russian government may itself finance construction of a second storage facility at Chelyabinsk-65. Site preparation for the U.S.-funded facility will begin this summer at Tomsk-7, and it is scheduled to be finished in 1997.

Groundwater levels at the proposed sites are high, and Russians living nearby are concerned that plutonium will pollute the groundwater in their areas or that whatever is done with the pits in the future will contaminate the groundwater. Also, they fear that what started out as a storage site will end up as a site where plutonium is used to feed breeder reactors, says William H. Mitchell of the Nuclear Safety Campaign, a Seattle-based organization that works on issues related to the nuclear weapons complex.

All U.S. pits from dismantled weapons are being stored at the DOE Pantex plant near Amarillo. They are kept in 16 World War II-era concrete earth-covered bunkers called magazines. These have no electricity, climate control, or sprinkler systems. Physical barriers like the steel door, 2,500-lb concrete blocks in front of the door, and the heavy guard around the facility provide deterrents against theft. Workers wearing lead aprons place the metal barrels holding pits on the floor of the bunkers, but soon a shielded forklift will be used for this purpose. However, the very simplicity of the bunkers means little can go wrong with them. "Once you lock up a pit in a container inside a magazine," says Gerald Johnson, plant manager at Pantex, "the only accident scenario that was identified as a potential credible accident is an aircraft crash into one of the magazines." On the other hand, he does say that "if we build a new facility for the Russians, perhaps we should build one for the U.S. as well."

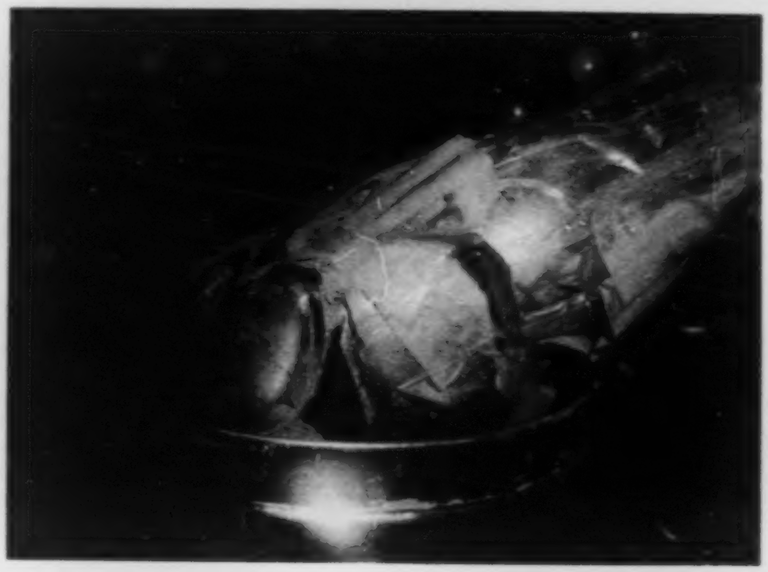
There are about 140,000 aircraft flights over Pantex each year. Most of the commercial flights are at high altitude, but military planes training at the Amarillo airport fly over relatively low. "We are working with the Department of Defense and the city of Amarillo to see if there is a way to restrict or reduce the number of military flights over Pantex," Johnson says. The containers used to store the pits are inferior to the ones the U.S is supplying Russia. But the U.S. will soon begin using a similar container, which will largely protect the plutonium in the event of an airplane crash.

The citizens who live near Pantex do not oppose disarmament. They are concerned, however, that if a more modern storage facility is built at Pantex and all of the pits are stored there, the pits will remain there for many decades. They are also concerned about groundwater contamination with plutonium in the event of an aircraft accident. Pantex sits on top of an upper aquifer at a depth of about 250 feet and the Ogallala aquifer 400 to 450 feet below the surface. Low levels of volatile organic compounds have shown up in the upper aquifer.

Beverly Gattis, head of the Amarillo citizens group Serious Texans Against Nuclear Dumping (STAND), wants DOE to seriously consider using sites other than Pantex for storing at least some of the pits. She says her group is very aware of environmental problems at many DOE sites and continues to be concerned about problems at Pantex because the "regulatory and bureaucratic structure that created the problems is still largely intact." Doris B. Smith, chairwoman of Panhandle Area Neighbors & Landowners, Amarillo, says storing plutonium from weapons and possibly processing that plutonium could be the greatest environmental risk ever posed to the area's agricultural-based economy.

Because of opposition of groups like STAND, DOE reached an agreement with the state of Texas promising to store a total of no more than 12,000 pits at Pantex over the next three years. Currently, about 5,000 to 6,000 pits from

Plutonium storage containers aren't fail-proof



Two nested plutonium storage vessels that originally held 2.5 kg of pure plutonium metal failed at Los Alamos National Laboratory in New Mexico in November 1993. Over a period of seven to 10 years, much of the plutonium was oxidized to plutonium oxide (PuO_2), expanding in the process and rupturing the inner storage vessel.

Originally, the plutonium had been placed in a metal tube with improperly welded caps. The tube was then covered with a polyethylene bag, sealed with tape, and placed in another, larger, metal container with a slip lid. Neither metal container was hermetically sealed.

Apparently, plutonium oxidation occurred in two stages. First, over a period of five to 10 years, fine particles of plutonium oxide were transported by thermal currents through openings in the inner vessel to the surrounding plastic bag. These caused radiolytic decay of the plastic releasing hydrogen, which moved into the inner vessel and reacted with plutonium to form plutonium hydride. Eventually, the embrittled plastic bag failed completely, exposing the plutonium in the inner container to the air in the outer vessel.

In the second stage, oxidation proceeded very rapidly because it was catalyzed by plutonium hydride. The free volume of the inner vessel was filled with plutonium oxide, which has a volume about 40% greater than that of pure plutonium, until the inner vessel ruptured. From that point, the reaction proceeded even more rapidly. If the process had gone on long enough, the oxide would have ruptured the outer container as well.

The container at Los Alamos contaminated workers' clothing as they removed it from a vault, but the workers did not absorb any of the plutonium oxide, and none of it was dispersed to the environment.

A similar incident occurred in a facility in the U.K. There, plutonium oxide ruptured both the inner and outer containers and released oxide to the shelves where the metal was stored.

In December 1993, the Department of Energy (DOE) sent out an advisory to its labs and facilities warning that all plutonium containers should be inspected periodically to determine whether the plutonium is undergoing rapid oxidation. Also, before handling, plutonium packages should be taped or placed in plastic bags to reduce the possibility of venting oxide to the air, DOE says. Currently, DOE is inventorying the plutonium at its facilities and, at the same time, determining how well it is stored.

Much of the plutonium that is not in weapons components is likely to be stored with plastic at DOE facilities. "All of this material at this point has to be considered suspect," says Joseph C. Martz of the nuclear materials technology division at Los Alamos National Laboratory. "Much of it is stored in uncharacterized containers."

the weapons dismantlement program are kept there, and by 2003, a total of about 20,000 pits will need storage at Pantex or at some other site.

At DOE, an agencywide group led by Robert W. DeGrasse Jr. is preparing what is called a programmatic environmental impact statement. It will analyze the environmental impacts of plutonium pit storage at Pantex and at other potential sites, including military bases. It will also assess the affects of the many different proposals for plutonium disposal, including those recommended by NAS. As a part of this effort, an implementation plan will be finished by fall, and DOE will make a final recommendation on plutonium disposition in 1996.

An interagency working group chaired by Frank von Hippel of OSTP is attempting to ensure that all of the relevant agencies—including the Defense Department, State Department, and Environmental Protection Agency—are listened to on the issue of plutonium storage and disposition. Von Hippel's group also forms the U.S. side of a joint U.S.-Russian working group that is trying to find a way to provide safe and secure storage of Russian fissile materials to guard against theft and hijacking.

Plutonium not in pit form

Weapons-grade plutonium is stored at 43 DOE sites in many forms other than pits. Excluding plutonium-containing waste, plutonium is kept as pits, pure metal, oxide, scrap, and nitrate and other solutions. In some ways, the plutonium in these other forms, which totals about 33.5 metric tons, presents more of a proliferation risk than do the pits because it is scattered across many facilities that are less well guarded than Pantex, and some of it is not packaged or inventoried well. For example, much of the plutonium is stored in an inner metal container, sealed inside a plastic bag, and that assembly is placed in an outer metal container. If small leaks develop in the containers, and often these are not hermetically sealed, radiolytic decay of the plastic can release hydrogen that can catalyze rapid oxidation of the plutonium. Plutonium oxide has a greater volume than plutonium, so this reaction can cause the containers to break and contaminate storage areas with the radioactive oxide.

In March, DOE began a nationwide review of its vulnerabilities in storing and handling plutonium. The purpose of the review is to inventory weapons plutonium at DOE facilities and to check for "conditions or weaknesses that could lead to unnecessary increased radiation exposure of workers, release of radioactive materials to the environment, or radiation exposure to the public."

Last month, analysts at the Natural Resources Defense Council announced a discrepancy of 1.5 metric tons between their calculation of total weapons-grade plutonium production and the 89 metric tons Energy Secretary Hazel R. O'Leary announced in December. The 1.5 metric tons, though a small portion of total production, is enough to make 300 nuclear weapons.

DOE admits that there are discrepancies in its plutonium accounting, but says these are mostly the result of technical and paperwork problems. The vulnerability study, which is slated to be finished Sept. 30, will establish a more accurate inventory of the material.

CONFERENCE UPDATE

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Bilateral arrangements

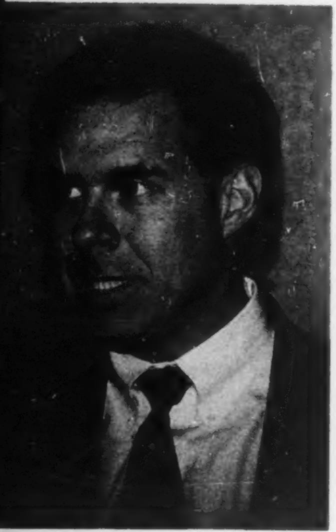
In addition to providing storage containers and funds for a storage facility for Russian pits, the U.S. has made a number of bilateral arrangements with Russia to help stem the spread of nuclear materials. At their Jan. 14 summit meeting, President Clinton and President Boris Yeltsin agreed to nonproliferation goals. On March 16, O'Leary and Russian Minister of Atomic Energy Mikhailov signed an agreement that will permit mutual inspection of plutonium storage facilities. Russian inspectors will be allowed into the Pantex facility, and U.S. inspectors will be allowed to inspect plutonium facilities at Tomsk. Neither side will be permitted to see the actual pits because that would give away sensitive weapons design information. But they will take radiation measurements of the containers that will reveal whether pits are stored there. The details of the inspections haven't been worked out.

In another pact, Russia has agreed to shut down its three remaining reactors that produce plutonium for weapons and also generate power for the cities of Tomsk and Krasnoyarsk, by 2000, when alternative power sources will have been built. In return, the U.S. will help Russia obtain financing for alternative power plants. In the meantime, Russia will continue to separate weapons-grade plutonium from the spent fuel from these reactors, but has promised not to use the plutonium in new weapons. It says it has no storage space for the aluminum-clad fuel rods and that they will corrode if not reprocessed.

The U.S. has promised to put its surplus stocks of highly enriched uranium and plutonium under inspection by the International Atomic Energy Agency and is now in the process of deciding what stocks are surplus. The Nuclear Weapons Council, a group composed of representatives from DOD, DOE, and the Joint Chiefs of Staff, has made an initial decision that is now under review. Also, the U.S. has pledged to produce no more weapons-grade plutonium or highly enriched uranium. Facilities that manufacture these materials have been shut down for a number of years.

In addition, the U.S. has promised to be much more open in most of its policies regarding plutonium. As a part of this new openness, O'Leary announced that the total U.S. production of weapons-grade plutonium was 89 metric tons and supplied a list of the major amounts of plutonium that are stored at various DOE sites. The purpose of the new openness is twofold. One goal is to gain trust and eventually public acceptance in the U.S. for whatever is done to dispose of plutonium. The other is to set an example

Gattis: pit storage raises environmental concerns



DeGrasse: openness advances nonproliferation efforts

for Russia and the rest of the world.

If the U.S. does not share certain information about its plutonium and reveal enough data to show it is actually dismantling as many weapons as it says it is, Russia will probably not reveal enough evidence to demonstrate that it is keeping its word. According to DeGrasse, "Openness advances U.S. nonproliferation efforts" and helps build public confidence in DOE, whose reputation is now at a low level. "DOE will find it is much more capable of achieving its goals if it can be trusted," he says.

No consensus

Because the White House generally favors one of the NAS disposal options and the majority of Russian government officials are determined to save their plutonium for use in breeder reactors, many observers believe the U.S. and Russia will not agree on the ultimate disposition of plutonium for many years to come. A Pentagon official says, "I really don't see any basis for agreement between the U.S. and Russia on ultimate disposition." There is nothing pushing them to make a choice, so "it's a decision that probably won't be made for 20 years, 10 years at the earliest," he adds. "Everyone can agree plutonium ought to be stored safely and securely. No one is going to agree on what to do next."

Mitchell of the Nuclear Safety Campaign echoes that view: "We just don't know how to proceed with the Russians, aside from the storage issue." The U.S. could go ahead unilaterally and destroy most of its plutonium while Russia stores its pits intact, but this would be entirely unacceptable politically.

Robert H. Socolow, director of the Center for Energy & Environmental Studies at Princeton University, sums up the current tension surrounding the first steps toward nuclear disengagement: "The production of nuclear weapons . . . has demanded single-minded dedication, isolation, and risks to personal safety on the part of individuals; sustained commitment on the part of political leadership; and large expenditures of public funds. Since 1945, no nuclear weapons have been used in war; they have 'kept the peace.'

"Small wonder, then, that those involved see themselves and their colleagues as unsung heroes and can only slowly comprehend that the time has come to undo all their work. Reversing the nuclear arms race will take tremendous political will in every country that has invested heavily in nuclear weapons. Rendering unusable for weapons the plutonium and highly enriched uranium that have been loved into existence will require a worldwide cultural shift. Yet, the alternative is a nuclear arms race that spreads throughout the world, and, eventually, nuclear wars from miscalculation or malfunction, with untold horror." ☐

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SOLVENTS

Regulations force massive shifts in the industry
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CHEMICAL & ENGINEERING NEWS
C&EN
JUNE 20, 1994

NEWS OF THE WEEK

- After months of interagency debate, Congress gets draft legislation for implementing chemical weapons treaty and holds a public hearing on ratification. Page 6
- In a development that represents a step toward the design of molecular electronic devices, researchers have made conducting filaments of polyaniline on a nanometer scale. Page 7
- Merck, the world's largest drug maker, names Raymond V. Gilmartin—an outsider with no pharmaceutical experience—as new president and chief executive after an 18-month search. Page 8
- Dow may consider bankruptcy option in the future if too many women opt out of proposed $4.2 billion settlement plan for silicone breast implants and pursue individual lawsuits. Page 8
- A jury finds that Exxon's reckless conduct caused the *Exxon Valdez* oil spill; damages of up to $16.5 billion may be claimed. Page 8
- Several research groups have purified, characterized, and cloned the blood platelet regulatory factor thrombopoietin; results have potential implications for cancer chemotherapy. Page 9

COVER: Lab worker tests new solvent for cleaning metal parts. Photo courtesy of Union Camp

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GOVERNMENT

Chemical companies in West Virginia's Kanawha Valley make public their worst case accident scenarios, informing the public how serious accidental releases could be and what the companies are doing to prevent them. **Page 22**

Congress receives policy statements from ACS on education issues, research funding, EPA's research budget, and the Administration's proposal to review the use of chlorinated compounds. **Page 26**

SCIENCE/TECHNOLOGY

German abstracting service specializing in chemical engineering fields, a joint venture of Bayer and BASF, boasts of stringent selection process and seeks to broaden subscriber base. **Page 30**

New process achieves 90% conversion of crude butadiene to styrene in two steps—cyclodimerization and oxidation—at potentially lower cost than conventional methods. **Page 31**

ACS NEWS

Proposals for increasing minority participation in chemical sciences and ACS result from recent ACS Board retreat. **Page 38**

PRELIMINARY PROGRAM

ACS's 208th national meeting in Washington, D.C., in August offers a broad range of technical sessions and activities; listing and highlights of symposia are included along with full general program and registration form. **Page 41**

BUSINESS

Organic solvents—being phased out of many products and industrial processes because of federal regulations addressing health and the environment—are being replaced by aqueous formulations, small-volume organics, and no-solvent technologies. Page 13

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LETTERS

Chemical calculator is here

Stu Borman, in his article "Handheld Chemical Calculator Is On Its Way" (C&EN, May 16, page 50), makes this new computer program (O. Bertrand Ramsay's program is not yet available in handheld calculator format) appear revolutionary. Indeed, it does appear to have many features that sound fresh, but the idea of a chemical calculator is not new. For the past couple of years, I have been using a commercial handheld calculator, the HP 48SX Scientific Expandable, which I would liken to the program Ramsay has been developing. Borman's unawareness of this calculator surprises me: College students all across the country are quite conscious of its existence.

This calculator, without accessories, allows calculations with units, does unit conversions for almost every imaginable unit, and solves mathematical equations. In addition, accessory cards are available for various uses. The HP Solve Equation Library accessory card is certainly a rival to Ramsay's program. This accessory card contains a wealth of chemical and engineering information. There is a library of chemical and engineering equations that displays not only equations, but also graphically demonstrates variables and their use. There is a table of chemical and engineering constants. This accessory card also contains a periodic table of the elements with a database of the properties of each element. These properties can even be viewed graphically as a function of atomic number.

With the accessory card installed, I can type in chemical formulas and, with the touch of a key, have the formula weight. Useful equations are selected from the various menus, variables input, constants automatically imported, and the equation solved. Because this is a versatile calculator and not dedicated to a single purpose, one can also carry out statistical analyses, graph data, calculate loan payments, keep track of appointments, or look up an associate's telephone number and address.

This calculator allows development of programs and libraries to take place on a personal computer. The programs and data are then downloaded to the calculator or stored on removable RAM cards. The HP 48SX's versatility and expandability make it every bit as useful as the program under development by Ramsay. The chemical calculator is not on its way, it's already here.

Douglas E. Wedman
Los Alamos National Laboratory
Los Alamos, N.M.

No respect

In her letter, "Respect for interviewees" (C&EN, May 30, page 2), Kathryn A. Hemker makes a very important point about an issue that is truly an embarrassment to the chemical profession. My personal experience perfectly supports her case relating the "deplorable treatment" that her husband received as an interviewee for academic and industrial positions in chemistry.

In early 1991, a certain large U.S. chemical company invited me for an interview about one-half year after I had initially inquired by mail about the potential of obtaining a research position with them. I took a day of vacation from my job in Canada and flew there for the interview. The whole process went extremely well, and when I left, I was almost offered a position. I was told that only a few formalities needed to get ironed out.

More than three months passed and I heard not a word from the company. I finally decided to phone and inquire about the fate of my application. A very feeble apology for the delay was followed by news that the funding for the position for which I was interviewed did not materialize. Why did they fly me down there if they were not certain that a scientific position was available?

Luckily, I had a reasonable chemistry job at that time in Canada and consequently I was not very bothered by the outcome. What did amaze and shock me was exactly what Hemker describes so well in her letter—the total lack of respect that was shown toward me by the representatives of the very highly respected chemical company that had interviewed me.

Incidents of this sort are a sad reflection of the acute deficiency of humanistic thinking that exists among today's technical leaders, and that is perhaps most evident in the chemical world.

Walter V. Cicha
Newark, Del.

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Environment, Health Concerns Force Shift In Use Of Organic Solvents

■ ***Federal regulations favor aqueous formulations, as well as no-solvent technologies and small-volume alternative organics***

Elisabeth M. Kirschner,
C&EN Northeast News Bureau

Once the medium of choice for organic chemistry, many organic solvents are being phased out of products and processes for environmental and health reasons. Historically, solvents have been used to mobilize solids, preparing them for reactions; to carry particles onto surfaces in coatings, then evaporate; and to clean parts and equipment by separating grease and grime and carrying them away.

Petroferm photo

Technician evaluates CFC alternative for cleaning electronic parts.

Industry is minimizing or eliminating solvents to cut hazardous waste costs as well as Toxics Release Inventory (TRI) chemical emissions, as mandated under the federal Superfund law. Many companies are turning to aqueous carriers or high-solid contents in paints and coatings, and to hot-melt, ultraviolet-cured, and waterborne adhesives. In the cosmetics and personal care markets, solvents have been dropped from some formulations because of concerns about volatile organic compounds (VOCs). Water-based hairsprays and solid deodorant sticks have grabbed market share.

As solvent use continues its slow overall decline, demand for some solvents is shifting. Large-use chemicals that could dissolve seemingly anything—such as acetone, 1,1,1-trichloroethane, and xylene—are being replaced by myriad high-value specialty chemicals, each grabbing small niches. Such solvent replacements as aqueous-compatible organic solvents and nonsolvent technologies are enjoying growth.

The solvent market is dominated by Shell, Union Carbide, Exxon, Dow Chemical, and Eastman Chemical. According to industry consultant Freedonia Group, Cleveland, these companies accounted for 53% of U.S. solvent sales in 1992. Sales of the nearly $3 billion solvent industry are forecast to grow a sluggish 0.8% per year between 1992 and 1997, says Freedonia. It recently predicted a 1.6% per year decline in overall solvent demand by volume through 1997, falling from the 1992 level of 12.6 billion lb per year. But much of the major reformulations and process changes are already under way, says Freedonia; the 1987–92 period saw a steeper decline of 5.1% per year.

Many traditional solvents are on environmental "hit lists." Of the three main types of solvents—hydrocarbons, chlorinated hydrocarbons, and oxygenates—chlorinated solvents are facing the biggest challenges. Ozone depleters 1,1,1-trichloroethane and chlorofluorocarbon (CFC)-113 are nearing a Jan. 1, 1996, production and import ban under the Montreal Protocol on Substances That Deplete the Ozone Layer. Meanwhile, chlorinated solvents are under the general pressure all chlorinated products face, says SRI International senior consultant Eric Linak, referring to recent calls for banning use of chlorinated compounds.

Moreover, highly volatile organic compounds—smog precursors—have been removed from many applications and products because of strict California requirements.

Less onerous but more broadly applicable is the Environmental Protection Agency's TRI and 33-50 program, which calls for voluntary emission reductions of 17 chemicals, including six commonly used solvents. The 33-50 program is so named because companies agreed to reduce releases of the 17 listed chemicals 33% by 1992 and 50% by 1995, measured against 1988 TRI data. EPA says that in 1992, its 33% goal was surpassed, with companies achieving a 40% cut. Meanwhile, solvents on the 1990 Clean Air Act hazardous air pollutants (HAP) lists are already seeing a downward trend in demand, with new regulations scheduled for promulgation over the next six years.

Health concerns plague some solvents, such as monomethyl and monoethyl ethers and their acetates, blamed for high miscarriage rates among semiconductor industry workers.

As perchloroethylene use is reduced, dry cleaning may get wetter

Solvents are, by definition, the cornerstone of the dry cleaning industry, which is made up of 25,000 facilities in the U.S.

The industry is one of the major users of perchloroethylene, a suspected carcinogen and hazardous air pollutant, and the first industry to be regulated under the 1990 Clean Air Act's national emission standards for hazardous air pollutants (NESHAP).

In a partnership with cleaners and solvent makers, the Environmental Protection Agency has established a goal to reduce perchloroethylene emissions from the industry. Under EPA's Design for the Environment program, approaches range from tightening process operations to eliminating organic solvents with water-based "wet" cleaning methods.

Last year, EPA employees donated their dirty laundry to test the new multiprocess water and steam cleaning technology. Wearers rated the wet cleaning slightly preferable to standard dry cleaning, says EPA economist Ohad Jehassi, who helps coordinate the partnership. He warns that long-term results are as yet unknown. Two wet cleaners have since opened in New York City.

Multiprocess wet cleaning includes steaming out stains, pressing, and using soaps. Machine wet cleaning with washer extractors can be added to cut the amount of human labor. Microwave drying helps prevent shrinkage of wet-processed items.

The partnership is also examining supercritical carbon dioxide, which cleans under extremely high pressures, at very high costs. Other options include ultrasonic cleaning, hydrochlorofluorocarbons and hydrofluorocarbons, and the return of mineral spirits in new nitrogen-purged machines to reduce fire hazards. EPA is also considering an environmental certification program for dry cleaners.

Perchloroethylene was a miracle replacement for the flammable—and explosive—petroleum solvents of the early 1900s. Mineral spirits and ozone-depleting chlorofluorocarbon-113 continue to be used, but at low levels.

Cleaners have always recycled solvents through filtering and reuse, says William Fisher, International Fabricare Institute senior vice president for government relations and administration. And when perchloroethylene became subject to all the regulations for hazardous wastes, cleaners had to send still bottoms—the molasseslike dirt-filled solvent—to recyclers or incinerators.

Perchloroethylene use has already been cut by careful housekeeping and improved machines. Sales to the industry in 1993 fell 27% from 1986 to 200 million lb. In 1975, says Center for Emissions Control executive director Steve Risotto, the average "solvent mileage" was 8,000 lb of clothes per 55-gal drum of perchloroethylene. In 1993, the same amount of the chemical cleaned 16,000 lb of clothing.

In September 1993, dry cleaners received final regulations under the Clean Air Act's NESHAP program. The requirements, to be fully implemented by 1996, call for better work practices and record keeping, a fugitive emission prevention program, regular filter changes, and checks for leaks. Larger and new facilities must install refrigerated condensers to control process vent emissions. EPA says the move will cut emissions of perchloroethylene 37% from current levels of 96,200 tons, with 7,300 tons cut through captured vent emissions and 28,400 tons eliminated through leak detection and repair.

In addition, dry cleaners will no longer be permitted to purchase "transfer" machines. Transfer machines, which account for 25% of those in use, were the first dry cleaners. Essentially a separate washer and dryer, transfer machines allow much solvent to evaporate during the transfer of clothes. Newer dry-to-dry machines vent to absorbers or refrigerator condensers. Some evacuate the drum before the door is opened.

Fisher cites problems with many of the alternatives, such as the high pressure and cost of supercritical carbon dioxide and the possibility of damage to very delicate fibers from ultrasonics.

Although he doesn't want a rushed decision to eliminate perchloroethylene, it's a decision the dry cleaning industry would learn to live with. "We're a service industry," says Fisher. "We're not married to 'perc.'"

But where there are losers, there are winners. With the phaseout of ozone-depleting compounds, says Chem Systems vice president Larry Rosenberg, "a wide range of alternative products—[such as] aqueous blends, oxygenates, terpenes, *N*-methyl-2-pyrrolidone—are vying for market share." Because there is as yet no exact drop-in replacement, he says, the "range of suppliers is also diverse, including traditional solvents producers and numerous formulators."

Although use of ethylene glycol ethers is declining, demand for propylene glycol ethers is projected to grow. Similarly, although demand for the HAP-listed ketones, such as methyl ethyl ketone and methyl isobutyl ketone, will likely decline, use of the small-volume, nonlisted methyl isopropyl ketone and methyl amyl ketone probably will expand, says Shomik Majumdar, Frost & Sullivan industry analyst. Esters, with a clean bill of environmental health, "are definitely going to grow," he says, perhaps at 3 to 4% per year. Ethyl acetate could replace ketones, and *n*-butyl acetate, as well as isopropyl and *n*-propyl acetate, should also grow. The real winners, he adds, may be hybrid aqueous-nonaqueous solvents.

Users and producers are finding new solvent combinations and applications for low-use solvents. Almost everything used to be cleaned with CFC-113 or 1,1,1-trichloroethane, says Michael Hayes, vice president of technology at Petroferm, Fernandina Beach, Fla. Petroferm now has two solvent replacement lines, one based on the citrus-peel-derived terpene *d*-limonene and tropical-oil-derived esters, the other based on aliphatic and cycloaliphatic hydrocarbons.

ISP "engineered" solvents to replace environmentally harmful cleaners, degreasers, and paint strippers. Its six products are very specialized, niche-oriented, says Bianca Thayer, market development specialist for ISP. The firm has expanded its sales force to seven, and is adding a product to the line later this year. The products, based on *N*-methyl-2-pyrrolidone, γ-butyrolactone, and dipropylene glycol monomethyl ether, also include additives such as rust inhibitors and surfactants.

However, customers "have to change the way [they] clean," says Thayer. Most must abandon the vapor degreaser—a one-step process—for a dip-tank rinse and dry operation.

Decline in solvents use to continue at about 1.6% a year

Millions of lb	1987	1992	1997	% annual change 1987–92	% annual change 1992–97
BY TYPE					
Hydrocarbon solvents	8,282	4,735	4,000	–10.6%	–3.3%
Alcohols, esters, ethers	3,624	4,182	4,563	2.9	1.2
Chlorinated solvents	1,998	1,393	688	–7.0	–13.2
Ketone solvents	1,294	1,177	1,137	–1.9	–0.7
Glycols, esters, ethers	921	811	862	–2.5	1.2
Other	222	273	339	4.2	4.2
BY MARKET					
Coatings, printing inks, adhesives	10,081	6,826	6,091	–7.5	–2.3
Consumer markets	2,656	2,647	2,804	–0.1	1.2
Manufacturing & process	1,259	1,271	1,315	0.2	0.7
Industrial cleaning	1,481	1,112	672	–5.6	–9.6
Miscellaneous	864	715	707	–3.7	–0.2
TOTAL USE	16,341	12,571	11,589	–5.1%	–1.6%
TOTAL VALUE ($ billions)	$3.34	$2.85	$2.97	–3.2%	0.8%
AVERAGE VALUE (cents per lb)	20.5	22.7	25.6	—	—

Source: Freedonia Group

"There are so many alternatives now," says Jeff Dore, Ashland Chemical's business manager for the cleaning alternatives unit. "The customers are being forced to make decisions" and tradeoffs, he says. "Before, the chemistry made the decision for them." Vapor degreasing, the traditional method of metal and electronics parts cleaning, says Dore, "is going to become extinct."

In vapor degreasing, quick evaporation was an asset, but with the new cleaners, low volatility is key. Recycling and reuse of cleaners means that a new, higher priced product can be less expensive in the long run. A company that would require 100 drums of 1,1,1-trichloroethane may need only 35 to 50 drums of a replacement, says Dore.

Only 20 to 30% of Ashland's customers are in the process of changing from 1,1,1-trichloroethane, despite the January 1996 phaseout goal. Since all the alternatives have trade-offs, Dore says most users, particularly those with small operations, are reluctant to gamble on less than perfect replacement chemistry or new capital equipment before the deadline. Also, an alternative may become the target of new regulations. "They want a permanent solution," says Dore.

Ashland has blended seven alternatives to 1,1,1-trichloroethane. Introduced two years ago, they are based on hydrocarbon solvents and glycol ethers. Ashland is also beefing up its technology staff. "It's a different sell from what our [salespeople] are used to," Dore says. "We've gotten into a more specialized area that requires more of a technical sell, more technical assistance."

Customers may also be holding out for hydrofluorocarbons (HFCs). They will be very expensive, he says, but come closest to a drop-in replacement. DuPont expects to conclude toxicity testing on its HFC product 43-10 by the end of this year.

"We're hoping that it will turn out to be a big market, with a variety of applications," says Del Glover, DuPont vice president and global business director of fluorochemical cleaning agents. DuPont is pinning much of its hopes on 43-10 and other HFCs as replacements for CFC-113. DuPont may commercialize the product by the beginning of 1995.

For the transitional period, DuPont is selling perfluorocarbon solvents to a "very limited" market of customers—mainly in the military and aerospace industries. Customers ensure tight environmental controls on the solvent, suspected to be a major contributor to global warming.

Some have said that "growth and solvents are oxymorons," says Nigel Bell, Shell Chemical's business manager for solvents. "We have found that that is very much not the case." Shell, the largest solvents maker both in the U.S. and worldwide, has been increasing production at its solvents plants and has spent "several million dollars for rejuvenation" of its isopropyl alcohol plant in Deer Park, Tex.

Bell sees opportunities in replacement solvents and in the export market. For example, use of ketones is declining in the U.S. because they are included on the hazardous air pollutants list, but use is growing outside the U.S. Methyl ethyl ketone and methyl isobutyl ketone "are being embraced because they allow you to get aromatics out of paints," says Bell.

Environmental regulations have changed the way Shell views the solvents market. Only four or five years ago, solvents were a commodity market with price the main difference between suppliers. Now, producers must understand how their customers are using solvents. Shell has increased its marketing staff and increased research efforts over the past two years to respond to the changes.

The company has invested heavily in developing an "enormous" capacity in "hydrotreated" solvents at its Deer Park and Sarnia, Ontario, plants. Hydrocarbons are processed to remove aromatics, olefins, and sulfur, yielding low-odor, low-aromatic-level products.

Shell is also working with Ashland Chemical to market its diacetone alcohol shipbuilding cleaner to replace acetone. The alcohol has a lower flash point and one tenth the volatility of acetone, so it should be safer and last longer.

In addition, the cleaner is sold as part of a complete chemical service. Customers purchase the solvent, then return the exhausted product to Ashland to recycle it. Says Bell: "It's a trend that will develop more and more in the solvents business."

Dow Chemical, with a portfolio that leans heavily on the shaky chlorinated hydrocarbons, is restructuring its chlorinated solvents business. Dow has invested $100 million over the past three years in "sorting out our future [and getting the business] reconfigured and sized right," says senior product manager Jeff Sullivan. In April, Dow built up inventory to fill demand to the end of 1995, then shuttered its 500 million-lb-per-year 1,1,1-trichloroethane unit in Freeport, Tex.

In Stade, Germany, Dow is converting its 220 million-lb-per-year 1,1,1-trichloroethane plant to produce trichloroethylene (TCE), which has a future as a feedstock for HFC-134a. The conversion is to be completed by the end of this year.

At both Plaquemine, La., and Stade, Dow is pushing its perchloroethylene-

New programs help industry smooth the transition away from solvents

Solvent users don't have to go it alone. Almost every producer has a program to help users of embattled solvents switch to a new formulation or process. Dow Chemical has made a business of its Advanced Cleaning Systems program, and many other makers have computerized assistance to help find the best match for a working—but soon to be obsolete—paint formulation.

Dow Chemical's Advanced Cleaning Systems began in 1991 to help customers survive the phaseout of chlorofluorocarbon (CFC)-113 and 1,1,1-trichloroethane under the Montreal Protocol on Substances That Deplete the Ozone Layer and the Clean Air Act. 1,1,1-Trichloroethane "was by far the most used, easiest, and efficient cleaning solvent," eulogizes marketing communications manager Jon Kirst. "It is a very efficient molecule, the vapor is able to separate soil from a part without harming the part, there's no impingement, no distortion. It liked grease and oil. There really isn't an apples to apples replacement for it."

The best replacement depends on the item to be cleaned: A complicated multidimensional surface is harder to clean, and there are different levels of clean. For aerospace and medical uses, Kirst says, "it better be very clean." He says the company is completely independent from Dow's solvent sales: Advanced Cleaning Systems has directed some users to aqueous systems, others to solvents that can be used in a vapor degreaser system, and others to no-clean fluxes.

Kirst plans to continue the business beyond the January 1996 deadline to phase out ozone depleters. "We're already looking at other things we can offer," such as handling wastewater and volatile organic compounds.

Most major solvent suppliers offer computerized conversion assistance, says Ron Litton, principal technical representative and supervisor of the coating laboratory for Eastman Chemical. The programs are primarily for paint reformulations, but can help in developing cleaning solutions, too. Computerization has brought the response time down to days instead of weeks, or even just a few hours. "It depends on the complexity," he explains.

The programs were developed years ago for cost and performance improvements, or to deal with the shortage of a particular product. The programs can be fairly sophisticated, says Thomas Boyce, Dow Chemical's oxygenated solvents research leader. Dow's program contains a database of physical properties, such as flashpoints, thermodynamic functions, vapor pressure, and hazard evaluations.

"Now with the environmental issue, many requests are dictated by that," says Litton. Over the past five years, Eastman has added environmental models, tagging solvents with regulations that may limit their use. Reformulation—and use of the systems—has picked up over the past five years.

Water has also been added to databases as a solvent option. "The biggest difficulty in adding aqueous solutions is relative humidity," says Litton. Water doesn't handle the same way under different relative humidity levels. Organic solvents, on the other hand, tend not to be affected as much by humidity.

Chlorinated compounds, because of their low flammability, are difficult to replace. For aromatics, the user can combine oxygenated hydrocarbons and aliphatics to mimic toluene or xylene. "The likelihood of a one-for-one replacement is less than 10%," says Litton, "and nine times out of 10, the costs will rise."

The program at Eastman was written by chemists with some computer training. To begin, a user enters the current formula and the new requirements. The computer then calculates key parameters, and finds other combinations that match those parameters. "We focus on solubility constants and evaporation rates. If we can match those two parameters, we are a long way to our goal," Litton says.

But that's as far as the program will help. Then an experienced chemist will examine the computer's recommendations and eliminate obvious problems, such as flammable acetone for a use that would be compromised by flammability. Laboratory tests of promising mixes might follow.

"It really takes someone with application experience to sit down and have a look at [the results]," says Hoechst Celanese staff applications chemist Donald Raff. "Computers just spit out numbers. Some of this is an art."

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carbon tetrachloride "swing" plants to 100% perchloroethylene production through hardware modifications, repiping, and altered process conditions. Nearly 98% of carbon tetrachloride is used as a feedstock for ozone depleters CFC-11 and CFC-12, which are scheduled for phaseout at the end of 1995. Carbon tetrachloride has suffered reduced use as a solvent because of toxicity concerns, says Sullivan, although it is still used as a cleaning solvent "in very closed conditions."

Despite perchloroethylene's future as a feedstock for HFC-134a, overall use has dropped because of changes in the dry cleaning industry and phaseout of ozone depleter CFC-113, for which perchloroethylene is a feedstock. Dow's Aratu, Brazil, perchloroethylene-carbon tetrachloride plant will stop production this summer. In 1992, Dow shuttered its Sarnia plant. Its plant in Pittsburg, Calif., closed in 1991.

Meanwhile, Dow has expanded capacity for chloromethanes. Its Plaquemine plant, operational at the end of 1993 after process improvements, is now producing methyl chloride, methylene chloride, and chloroform. The company also slightly increased chloroform production at its Freeport plant, following an increase in demand for chloroform as a feedstock for hydrochlorofluorocarbon (HCFC)-22.

"People are going to take the worst solvents out first, and the best ones are those that are remaining," says Fred Schillinger, business director for solvents and intermediates for Union Carbide. "As the other solvents are reduced, oxygenated solvents make up some of the difference."

And Carbide's oxygenated solvents portfolio, according to Freedonia Group, is already the largest in the U.S. In 1992, Carbide had $237 million in sales of alcohols and esters, $76 million in glycol ethers, and $25 million in ketones, Freedonia says. A Carbide spokesman says those numbers are low.

The company is increasing capacity for its oxo alcohol and butanol area, with a 300 million-lb-per-year expansion due on stream in January 1996 at its Taft, La., plant. "Solvents like alcohols—including butanol—and solvents like esters—butyl acetate or isobutyl acetate, which are derivatives of butanol—are not under the same kind of pressure [because] they're not on a HAP list or a [TRI] list." Schillinger says demand is growing for butanol and butyl acrylate—which are used in water-based paints—at 4% per year. Carbide introduced specialty solvents based on ethyl 3-ethoxy-propionate and on butyl propionate and pentyl propionate a few years ago.

Glycol ethers that have not been implicated in causing health problems have been tarred by EPA's broad brush, says Schillinger. EPA's HAP list includes glycol ethers, not specifically the ethylene-based versions implicated in increased miscarriages. Glycol ethers "could be hurt if they stay on the list," he says.

In March, Carbide expanded its butyl glycol ether facility at Seadrift, Tex., by 80 million lb to 240 million lb a year and will continue methyl glycol ether production at its Taft plant to supply the jet fuel market, although the semiconductor market has been lost because of health concerns. The company is also repositioning and repricing its specialty solvent hexyl glycol ether to encourage use. "We hope it can grow substantially," he says, although it will "never be a 100 million lb product."

Monsanto is starting up a dimethyl ester line at its Pensacola, Fla., plant at the end of this month or early in July. "This stuff's fairly benign in the world of solvents," says Gary Winfield, Monsanto's market development manager for specialty resins. "There are no known health effects, [and the solvents are] readily biodegradable in five to seven days."

The move also cuts Monsanto's waste disposal costs, since raw material for the dibasic esters is harvested from the waste stream of its adipic acid unit. The acid waste is then converted and purified. Monsanto is developing six products from three coproduced esters—dimethyl glutarate, dimethyl succinate, and dimethyl adipate. With a total capacity of 20 million lb a year, the six products include the pure esters and blends that compete with DuPont's series.

DuPont has tapped its adipic acid line for dibasic esters for nearly two decades, says DuPont's product development manager, Lisa Boothe. The esters can be used for cleaning or as carriers in paints and coatings, with the "added value" of low toxicity and low volatility. There's been steady growth for the dibasic esters over the past five years, she says, with anticipated growth of 5 to 6% over the next few years. DuPont's adipic acid plant in Singapore, due on stream next year, will yield a large new source for the company. Monsanto's gambit, she says "reaffirms market growth for dibasic esters."

Exxon has focused attention on its specialty solvent product lines. It is betting on aliphatic isoparaffins and normal paraffins, as well as heavy aromatics and dearomatized aliphatic hydrocarbons. Says Ross Shirkey, Exxon's sector planner for differentiated hydrocarbons, the isoparaffins' narrow boiling ranges optimize formulations, and the dearomatized aliphatics promise low toxicity and reduced odor.

However, Exxon is not cutting back production of the traditional hydrocarbon solvents. "Very often [replacements] are not drop-in solutions," says Shirkey. There is "a certain amount of inertia" keeping customers from changing, and many are waiting to see how the alternatives shake out. "We'll see more and more converting as customers see their competition going to safer value-added products," says Shirkey.

Eastman Chemical is also continuing production of traditional solvents at the same level, says Eric DeLoach, business manager of coatings, inks, and resins. Some of the government regulations under the Clean Air Act aren't due to take effect until after 2000, he explains, so formulators have five to 10 years until the regulations actually go into force.

That's not to say that Eastman hasn't put its hat into the alternatives ring. Eastman entered the specialty solvents market in the 1960s to 1970s with methyl amyl ketone and methyl propyl ketone. And as paint and coating mixes move toward water-based solvents, the company's ester alcohol finds a place as a coalescing aid and the ethylene glycol monobutyl ether finds a place as a coupling solvent in the mix.

Environmental concerns have been a mixed blessing for Hoechst Celanese's acetate esters and acetic ester solvents, says Ken Stelts, marketing manager of the solvents business group. Methyl ethyl ketone and methyl isobutyl ketone were affected the most, declining 3% per year. "On the positive side, acetate esters are not listed [as HAPs]. They are benefiting as substitutes for toluene, xylene, and ketones," growing at 4 to 5% per year.

Late last year, Hoechst Celanese announced a process improvement initiative to increase production of acetate esters 25%. "I think we have some further options," Stelts adds.

Hoechst Celanese is also betting on Methylal, its methylene dimethyl ether specialty solvent. Now used primarily as an intermediate in the manufacture of ion exchange resins and as an extraction solvent for pharmaceuticals, Methylal could replace chlorinated solvents or be a cosolvent in aqueous systems, he says.

For users, a hierarchy of environmental concerns drives solvent choice, says John Carberry, DuPont's director of process and environmental research and development. "We concentrate on what should be attacked, from acutely toxic ones, such as benzene and methylene chloride," to ozone depleters, flammables, global-warming compounds, smog precursors,

Most common solvents are included in regulatory listings

	Toxics Release Inventory	33–50 program	Clean Air Act[a]
Acetone	■		
Acetonitrile	■		■
n-Butyl alcohol	■		
sec-Butyl alcohol	■		
Chloroform	■	▒	■
Dimethyl formamide			■
Ethyl benzene	■		■
Ethylene glycol	■		■
Glycol ethers	■		■
Isophorone			■
Hexane			■
Methanol	■		■
Methyl chloride	■		■
Methyl ethyl ketone	■	▒	■
Methyl isobutyl ketone	■	▒	■
Methylene chloride	■		■
2-Nitropropane	■		■
Perchloroethylene	■	▒	■
Toluene	■	▒	■
1,1,1-Trichloroethane	■	▒	■

[a] Hazardous air pollutants listing.

Sources: Hoechst Celanese, Eastman Chemical, EPA

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Carberry says as many as 70% of DuPont's businesses use a solvent, and the company is examining them for opportunities to reduce the number or amount used. "The best solvent is no solvent at all," he says, an attainable goal in some projects. Coating and casting operations are going to high-temperature no-solvent melts, but with some concern about thermal degradation. Water is the next preferred solvent, with gains in surfactant research in the 1960s and 1970s making aqueous solutions more effective. "Unfortunately," says Carberry, "in the chemical industry, water is not a good solvent."

Cleaning solvents are the easiest to change or eliminate, he explains. Less frequent cleaning, solvent recovery systems, and high-pressure water sprays can cut solvent use.

Solvents in process reactions, on the other hand, are more difficult to alter. "You're talking big money," he says. "Most [process solvents] influence the character of the product," such as the crystal shape. When a change is necessary, DuPont frequently opts for a flammable solvent as the least of the environmental evils. But that necessitates multimillion-dollar expenditures to prevent explosions, says Carberry.

Process solvents are highly proprietary, he adds, with most companies "working very, very hard" to find new formulations. Other options for preventing health or environmental problems include sealed systems and remote operations.

Since the 1970s, 3M has been moving away from solvent-based coatings on its products, which include adhesive tapes, abrasive papers, computer diskettes, and video cassettes. "We make about 60,000 different products," says Robert Bringer, staff vice president for environmental engineering and pollution control. "Three quarters [of them] have a coating operation."

With 20% of its R&D funding aimed at cleaner technologies, 3M has now converted about 25% of the processes to aqueous and nonsolvent technologies. The earliest changeovers were adhesive tape and packaging tape. Multilayer coatings are the most difficult, says Bringer, because each layer must be compatible with the others. Videotapes present a special challenge. "Magnetic recordings are gaining by leaps and bounds in terms of density of recording area, requiring thinner and thinner coatings. That goes against the grain when you are [trying to eliminate] solvents."

In addition to the phaseout of two of its cleaning fluids, the semiconductor industry has also been grappling with the ethylene-based glycol ethers. Studies have linked their use to an increased rate of miscarriages among industry workers. In December 1992, after the Semiconductor Industry Association (SIA) completed a health study that corroborated other research, most members agreed to phase out the use by the first quarter of 1995. Possible replacements, says SIA director of environmental and safety affairs Lee Neal, include ethyl lactates and propylene-based glycol ethers.

Because of military specifications, not all users will abandon the solvent, but "the days of ethylene-based glycol ethers in this industry are numbered." Neal—who says only 2.5% of the use is in the semiconductor industry—is pressing for reductions of ethylene glycol ethers throughout industry.

In the personal care business, "Everybody is looking for safe solvents," says Martin Rieger, a consultant to the Cosmetics, Toiletries & Fragrances Association.

Toluene has been pushed out of many nail polish formulations because of toxicity concerns and challenges based on carcinogen labeling required by California's Proposition 65, a ballot initiative passed in the state several years ago. Anecdotes of water-based nail polishes abound, in which unnamed companies were thrilled with results—until the tester washed her hands.

Rieger says water-based formulations with surfactants lose efficacy, but some activity can be restored with propylene glycol. For perfumes, he says, "you simply cannot make a clear product without alcohol." Deodorants long ago evolved from aerosol sprays, and the market is heavily represented by solids.

Water is beginning to live up to its title as "the universal solvent" throughout industry. Aqueous-based products are taking over much of the market for cleaning parts and equipment. And new surfactant and emulsion technologies are advancing water-based coatings and adhesives.

Cleaning out reaction vessels in batch processes is one high-volume use for solvents that is a target for aqueous re-

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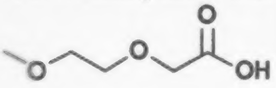
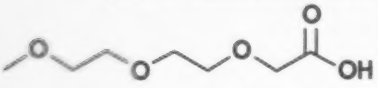


3.6.9-Trioxadecanoic acid



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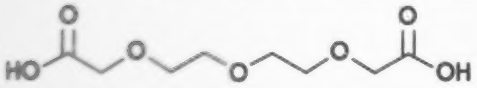
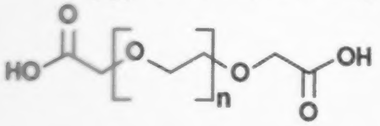


Polyglycol diacid (n = 10 - 12)



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placements. Solvents are a part of Monsanto's pollution prevention effort. Of the 57 million lb of emissions reduced between 1987 and 1992, says Monsanto director of regulatory management Dennis Redington, 10% would normally be classified as solvents.

Pharmaceutical operations, he says, need to be cleaned to less than parts-per-million contamination. In switching to high-pressure water for some of the applications, Redington says Monsanto has cut air emissions 87%, wastewater discharges 71%, and costs by $500,000 per year. Monsanto also found ways to recycle and reuse 600,000 gal per year of waste solvents from manufacturing.

Many agricultural chemicals depend on solvents to mobilize reactants. Monsanto managed to move from chlorobenzene to water in the Lasso corn and bean herbicide formulation. The difficulty, he says, is getting active ingredients into small particles for emulsion. The production process keeps a careful eye on density control, using suspending agents to keep particles from settling, which extends the shelf life.

California's South Coast Air Quality Management District (SCAQMD) has waged "virtually an all-out full-scale attack" on emissions of VOCs, says Larry Watkins, SCAQMD's program supervisor for economic development and business retention.

"We've been focusing on the end users," he says, adding that every manufacturer has complied, because southern California "is a big market."

The biggest new cleaners in the area are water and elbow grease. "Water works," says Watkins. "Water has been shown to work probably in 85 to 90% of processes and products." Using surfactants, emulsifiers, and mechanical cleaning, manufacturers have introduced thousands of aqueous formulations. It used to be, he says, that with a regular solvent based on VOCs, cleaning action was "90% chemical, 10% mechanical. Nowadays, cleaning is 90% mechanical."

Environmental and health concerns have changed the solvents industry—and downstream products—for good. Some of the qualities of the banned and embattled solvents may never be replicated by replacements. "The world is going to have to get used to the difference," says Monsanto's Winfield. Carbide's Schillinger agrees: "There's only so much you can do with chemistry." ☐

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C&EN
JUNE 27, 1994

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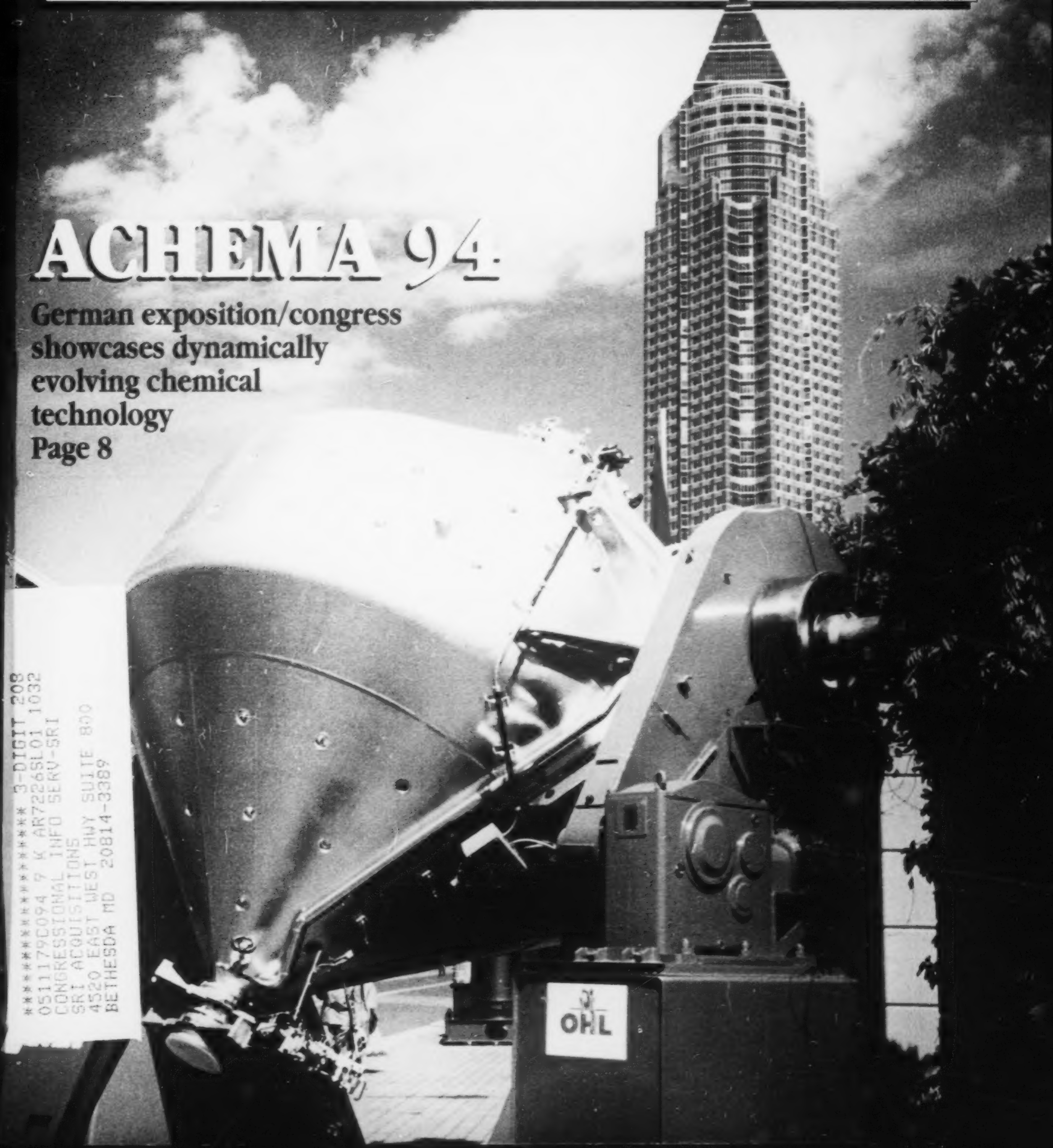
LAB CHEMICAL FIRMS GRAPPLE WITH RESPONSIBLE CARE ISSUES PAGE 31



ACHEMA 94

German exposition/congress showcases dynamically evolving chemical technology
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CHEMICAL & ENGINEERING NEWS

C&EN

JUNE 27, 1994

NEWS OF THE WEEK

- OxyChem agrees to pay New York State $98 million to settle their 14-year legal battle over the contamination and cleanup of the Love Canal area. **Page 4**
- Evidence that tobacco companies manipulate the nicotine content of cigarettes is described by FDA head Kessler at a House hearing. **Page 5**
- Unilever scientists reveal some of the chemistry behind a controversial new detergent formulation, based on catalysis by organomanganese complexes. **Page 5**
- An explosion during chemical synthesis rocks United Chemical Technologies plant near Philadelphia, injures 31 people. **Page 6**
- Extraordinary enhancement of enantioselectivity by use of a magnetic field—reported in a paper published in February—has been found to be based on fraud by a graduate student. **Page 7**
- "That's the way the ball bounces" takes on new meaning as an improved plastic soccer ball debuts at the World Cup championship matches. **Page 7**

COVER: Photo courtesy of DECHEMA

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BUSINESS

Companies that make and market lab and research chemicals see acquisitions as key to competitiveness in an industry facing increasing obligations under Responsible Care program. **Page 31**

Chemical sales pick up in most European countries, but employment in the European chemical industry continues to decline for the fourth consecutive year. **Page 33**

GOVERNMENT

National Academy of Sciences' forum on scientific integrity draws more than 200 university, government officials into lively discussion on promoting ethical conduct in research. **Page 35**

Clashing provisions in Administration's pesticide reform legislation spark debate at Congressional hearing. **Page 37**

SCIENCE/TECHNOLOGY

Unsteady-state catalytic oxidation process that removes volatile organic compounds from industrial exhaust streams is becoming available in the U.S. **Page 42**

BOOKS

"From Chemical Philosophy to Theoretical Chemistry," a well-written sociological history of chemists and physicists falls short as a history of chemistry and physics. **Page 44**

ACS NEWS

ACS member dues for 1995 will remain at this year's level, but division and local section allocations will rise modestly. **Page 48**

NEWS FOCUS

ACHEMA 94, Germany's triennial chemical engineering exhibition and congress, showcased products and developments in traditional sectors, highlighted frontier areas, and attracted more than 3,400 exhibitors despite strained European economies. Page 8

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LETTERS

What is 'chemical'?

Michael Heylin's perception of what is "chemical" is as narrow, if not narrower than that of the public (C&EN, May 9, page 3). He states that "in the public mind, chemical is synonymous with synthetic chemical [and that] is a cultural, linguistic thing." Following this logic, the fact that chemists "perceive all tangible things as chemical in nature, with no fundamental difference between synthetic chemicals and those that occur naturally" is then also a cultural, linguistic thing; that is, the culture and linguistics of the scientific enterprise by which chemists have been trained and molded.

Furthermore, Heylin believes that the chemists' perception of chemical is "appropriate" so that we live in a "chemical world" and "totally chemical environment." Perhaps. However, is this the kind of perception that gives chemists and industrialists the poor image they have? Is this the kind of perception that allows chemical pollution? The top producer of chemicals is also the top polluter.

Heylin's view of education's role in this dilemma is also narrow, if not insulting. He states, "Well-conceived education programs are necessary but not sufficient for alleviating public concerns about chemicals." Alleviating public concerns is not education, it is propaganda and public relations. Education or being educated is to be capable of thinking and analyzing critically all the various aspects of a situation. He then states that "dialogue and understanding" are essential. I agree. But Heylin seems to simply humor public concerns that are "not well founded" or "just wrongheaded" with "dialogue and understanding."

With these kinds of sentiments, I agree with Heylin that "chemists have little chance of convincing the public about the chemical world."

F. C. S. Tsai
Department of Chemistry
University of British Columbia
Vancouver

The May 30 issue of C&EN (page 3) includes yet another attempt, this time by reader A. R. Patton, to come up with a sensible definition of the word "chemical." But a few pages later, in an ad, we read, "This creates some difficult challenges, as constant exposure to water, chemicals, UV degradation, and friction all take their toll." Once again, chemicals are the bad guys.

How can we expect the general public to get it right when we chemists, writing for chemists, can't seem to do so?

Rick Smith
Geneseo, N.Y.

D-Day, the 6th of June

Congratulations on your insightful editorial, D-Day, the 6th of June (C&EN, June 6, page 3). It was the best editorial I can remember in my 45 years of reading C&EN, and a pleasant surprise to an ex-combat infantryman of World War II.

In one short page you gave the ACS's tribute to those who stormed the beaches that day and gave a great history lesson as well. You gave credit to the significant role of the British and Canadians, recognized the enormous contribution of the Soviet Union in defeating Germany's ground forces, and identified D-Day as the key to the assumption of world dominance by the U.S.

More poignantly, you used D-Day to illustrate the incredible sacrifices of war, the utter confusion and chaos of infantry combat, and the importance of individual initiative in winning battles. But most of all, you showed some understanding of the effects of combat on the human psyche. Pretty good for a chemical magazine.

Dick Mansfield
Grantham, N.H.

I believe that the beach that gave the American troops landing on D-Day the most trouble was Omaha, not Utah, as stated in your editorial of June 6.

Thomas J. Curphey
Dartmouth Medical School
Department of Pathology
Hanover, N.H.

Editor's note: Curphey is one of several readers who have written to make the same point. They are correct.

Correction:

- June 20, page 3: An item in the table of contents misstated the name of the company involved in a proposed $4.2 billion settlement plan for silicone breast implants. The company is Dow Corning, not Dow.

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CEFIC sees better outlook for Europe in 1994

The Western European chemical industry is expected to benefit—if only modestly—from the economic recovery currently under way. That was the message from the European Chemical Industry Council (CEFIC) at its annual meeting, held this year at Lake Como, near Milan, Italy.

CEFIC's annual report, released at the meeting, showed that business conditions have paved the way for at least halting steps toward recovery, as the value of chemical sales began picking up in the chemical industries of most of the federation's member countries. The number of employees throughout the industry, however, continued to fall.

As newly elected CEFIC president Simon de Bree, chairman of the Netherlands chemical company DSM, put it, "It is clear that we have the worst part of the recession behind us. The pace of growth is increasing, although slowly."

After several years of recession in the European economy, 1994 likely will bring a modest recovery, with gross domestic product in Western Europe rising about 1.5% from last year, led by exports and investments, CEFIC's economists predict. Prospects in other industries such as automobiles, plastics processing, electrical engineering, and iron and steel—all of which are heavy consumers of chemicals—are brightening, with growth rates predicted at an above-average forecast of 2% this year.

That encouraging outlook, in turn, has led CEFIC to slightly increase its growth expectations for the Western European chemical industry this year. Chemical output is now expected to rise 2%. At the beginning of the year, CEFIC was predicting only a 1.5% rise. The modest increase is certainly an improvement over the 1% annual decline in chemical production in 1993.

The industry is seeing changes in trends that have traditionally paralleled growth in sales, however. For example, because of the clampdown on health care budgets by a number of Western European governments, pharmaceuticals have ceased to be the dynamic sector they used to be in the chemical industry. Growth in sales of the pharmaceutical sector in 1994 is expected only to match that of the chemical industry as a whole, predicts the CEFIC economic staff.

Higher than average growth in sales is forecast for coatings, organics, and plastics. On the other hand, growth in sales is expected to be modest for inorganics and detergents. Growth in fertilizer sales may decline.

Profit margins and capacity utilization rates have remained low throughout much of the chemical industry, CEFIC points out. As a result, although interest rates have been easing through the region, prospects for growth in sales are still too uncertain to justify any brighter outlook than a bottoming out of investment in plant and equipment this year into early 1995. Capital investment, by and large, is not expected to increase this year in real terms, CEFIC economists say.

Employment likely will continue to decline for the fourth consecutive year; this year's drop is expected to run at about 3%, or 60,000 employees. Altogether, some 200,000 jobs have been lost since 1990, the economists point out. Moreover, with labor costs forecast to increase faster than producer prices, the preservation of already fragile profit margins will necessitate new productivity gains.

Cost-cutting and productivity-boosting efforts must continue for any upturn to begin to solve the structural problems of the Western European chemical industry, CEFIC glumly concludes.

Sales up for many countries, employee levels still down

	% change, 1992–93	
	Sales	Number of employees
Germany	−4.8%	−7.0%
France	1.1	−1.9
U.K.	11.9	−3.9
Italy	4.5	−3.6
Belgium	−0.7	−1.2
Spain	0.4	−3.0
The Netherlands	−8.1	−4.5
Switzerland	6.3	0.3
Sweden	13.6	−2.7
Ireland	8.2	0.7
Austria	−5.2	−5.3
Denmark	−0.3	1.1
Norway	2.3	−4.8
Poland	46.3	2.3
Hungary	12.3	−4.1
Czech Republic	−6.6	−6.4
Slovakia	2.5	−19.3
Turkey	19.2	−2.6

Note: Countries listed from top in order of chemical industry sales.
Source: European Chemical Industry Council

However, those efforts will contribute to the industry's ability to compete, and according to de Bree, "Competitiveness will certainly be one of the main focal points of CEFIC in the next few years. It will be more difficult for the chemical industry to have its voice heard in Europe because of so many changes in the political field in Europe. This is all the more a reason to act together and speak with one voice."

As he sees it, "The global position of the European chemical industry is under threat. The competitive position has seriously declined compared with [that of] the U.S. chemical industry."

The chemical industry is not an exception in Europe, he pointed out. Other industries are also coping with a deteriorated competitive position. One result is that European nations' governments and the European Union (EU) are addressing the problem and working to establish a framework for maintaining or promoting industrial competitiveness. Enhanced competitiveness is particularly important in areas such as biotechnology issues, energy costs, mergers and joint ventures within the EU, and EU R&D programs.

On another front, CEFIC delegates were cheered by findings of a survey on the image of the chemical industry in Europe, conducted early this year in Belgium, the Netherlands, Spain, Italy, France, Germany, and the U.K. This survey followed an earlier effort by CEFIC in 1992.

According to de Bree, "The public largely recognizes the economic relevance of the chemical industry, and it also recognizes the progress made in environmental and safety performance. Moreover, the public is perceptive to more information" from the industry.

"The industry is becoming more credible as a source of information, and the public seems to be more interested in the chemical industry, which gives us a better chance for a constructive dialogue," says de Bree. "This may be the early fruit of the Responsible Care program," which CEFIC and its member national associations have put much effort into implementing. However, he adds, "much more has to be done before the public will have a sufficient understanding of and confidence in our industry."

Patricia Layman

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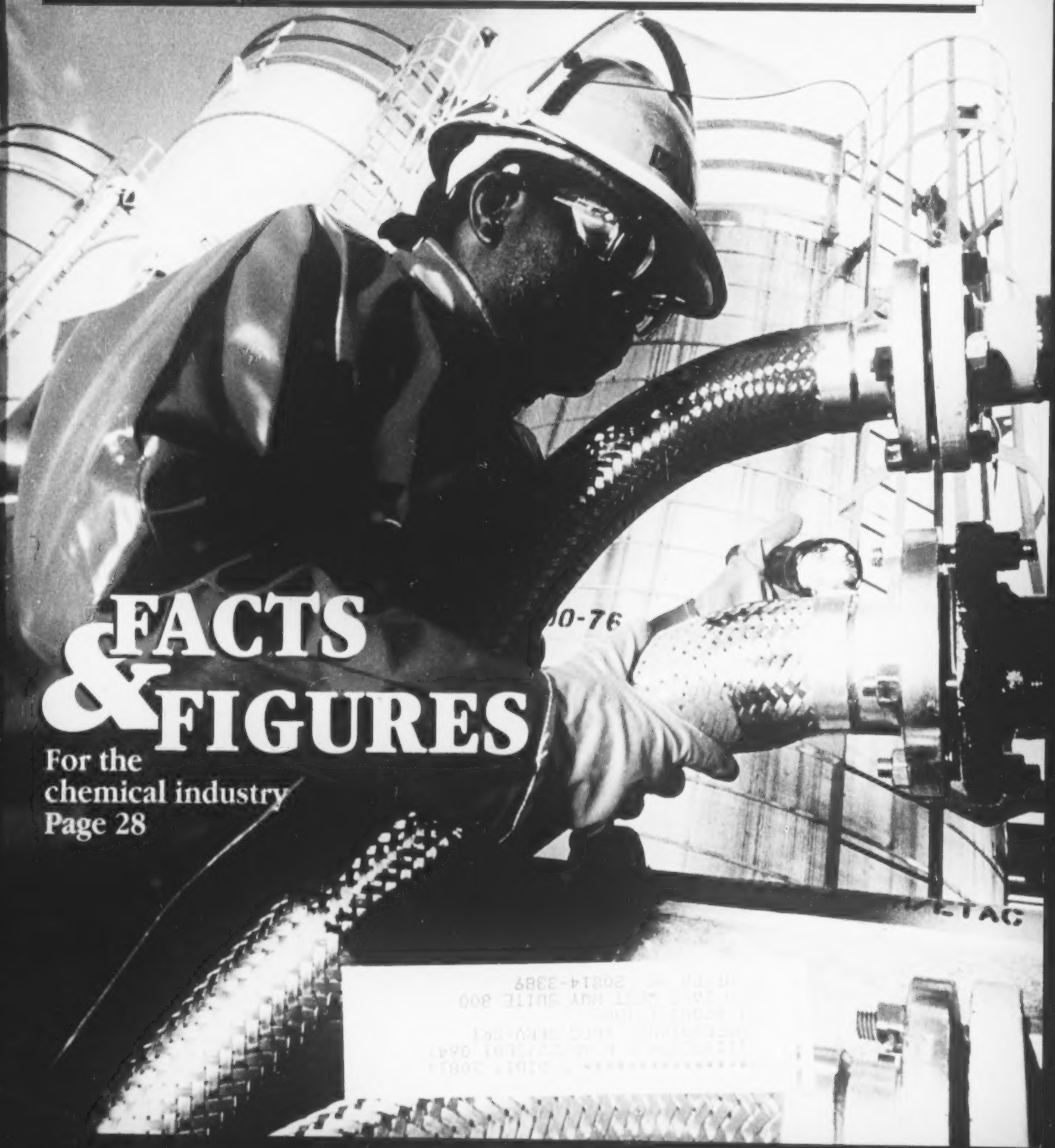
CALENDAR OF MEETINGS OF INTEREST TO CHEMICAL SCIENTISTS PAGE 79



FACTS & FIGURES

For the
chemical industry
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NEWS OF THE WEEK

- The long-sought target of the immunosuppressant drug rapamycin in mammalian cells—a previously unknown protein—has been discovered independently by four research groups. **Page 6**
- Scientists report that trifluoroacetic acid—a major breakdown product of leading CFC substitutes—is degraded by soil microbes and thus may cause less environmental harm than originally feared. **Page 7**
- Mobil Corp. will eliminate 2,300 jobs from its chemical businesses—reducing work force by nearly 20%—and close some plastic production facilities as part of restructuring program. **Page 8**
- Eli Lilly and Somatogen agree to collaborate in the development, clinical testing, production, and marketing of genetically engineered hemoglobin—a blood substitute product. **Page 8**
- Solvay Polymers modifies resin production processes, uses vegetable stearates to make polyethylene and polypropylene for food packaging that meets kosher certification standards. **Page 9**
- Four top high school chemistry students are named members of U.S. team to compete in the 26th International Chemistry Olympiad in Oslo, Norway. **Page 9**

COVER: Employee checks raw material supply line in Albemarle's Orangeburg, S.C., ibuprofen plant

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BUSINESS

Producers of chlorofluorocarbon alternatives boost output as 1996 phaseout deadline approaches, but illegal supplies of CFCs may reduce demand for new products. **Page 12**

Specialty chemicals producer Witco opens on the German stock exchange in a show of the company's commitment as a supplier to the European market. **Page 14**

Business Insights: Business Roundtable, a lobbying group, calls for government to reengineer the regulatory process. **Page 15**

GOVERNMENT

Congressional committees return to issues such as competitiveness, worker safety and health, and NSF reauthorization after intense debate on health care reform. **Page 18**

Chairman of new panel on research ethics decries apathy of scientific community toward scientific misconduct. **Page 20**

SCIENCE/TECHNOLOGY

A molecular sieve with novel structural features has been synthesized by Mobil Research & Development for catalytic applications in petrochemistry. **Page 23**

EDUCATION

Hoffmann-La Roche presents awards for a new scholarship program honoring excellence in organic chemistry as part of its outreach to graduate students. **Page 24**

MEETINGS

C&EN's semiannual calendar lists scientific meetings and events scheduled through July 1995. **Page 79**

FACTS & FIGURES

C&EN's annual statistical survey of the chemical industry in the U.S. and abroad finds that most indicators of industry health—earnings, sales, shipments, and profitability—moved upward in 1993, although employment, capital spending, and R&D budgets either dropped or remained at 1992 levels. Page 28

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LETTERS

Insights on the economy

The article on interest rates by William Storck (C&EN, June 6, page 19) was far more insightful than intended. Admittedly, these observations will represent hindsight to some degree but in doing so will provide a benchmark on economists as well as economics.

The author mentions the analogy of the Federal Reserve Board's control as taking away the punch bowl just as the party is getting good. Unfortunately, this trivializes the situation. What the Fed did was more akin to inserting a control rod in a nuclear process that was going critical and headed toward meltdown and fallout. The economy itself was not becoming overheated—it was the market, which was assuming an identity independent of the economy that it ostensibly represented.

This was true because stock values no longer represented a valid evaluation of the businesses supporting the stocks. Price-earnings ratios and dividends bore little relation to the stock values. The stock values were dependent on future purchasers bidding the prices higher, which is known in some circles as "the greater fool" concept, and in others as the Ponzi Principle. In addition, leveraged speculation called derivatives was betting on anything from commodities to interest rates to market averages. It was a potential replay of 1929 in which the boom was followed by a bust that had an economic fallout extending far beyond the market itself. Whether this was the goal or thinking of Greenspan and the Fed is impossible to judge, but if the market begins to go critical again, speculators beware.

But a second point may be made. The June 13 issue of *Fortune* comments that there is no inflation in the near future—that bondholders may feel secure. Yet the June 27 issue carries an in-depth evaluation of price rises in a number of basic commodities. Are the data incorrect, or the economists, or does this indicate a problem having to do with economics and the U.S. economy? Or did Greenspan know more than he was telling? What it may indicate is that the U.S. economy is very thin, that supply is relatively inelastic so that a small change in demand results in a relatively large change in price.

This is reflected in the dispute concerning the rate of unemployment, which will not result in wage increases. Is it 6.2% or 5.9%, and what will the Fed target as the correct interest rate to achieve the optimum unemployment rate as it takes inflation into account?

The proper answer is that these considerations involve fiscal policy and the relationship to society. The overemphasis on monetary policy and infrastructure while ignoring fiscal policy and social infrastructure may have put us in an inextricable position.

Leonard Clapp
Wilmington, Del.

No 'coincidence'

Regarding the "intriguing pattern" in atomic numbers of man-made elements (C&EN, June 13, page 4), every chemist should know that nucleon "configurations," like their electron kin, are governed by quantum mechanics, and that it is no "coincidence" for nuclear properties to exhibit periodicity where numbers of protons differ by "filled shells" of $2(2n + 1)$.

Peter Green
California Institute of Technology
Pasadena

Bader's contributions

I applaud the selection of Alfred Bader for the 1995 Parsons Award. By his long and distinguished service, Bader has earned a unique place in organic chemistry. The Aldrich catalog became the standard reference on many desks. One of his imaginative and helpful contributions has been the "ABC Library of Rare Chemicals," in which collections of research samples from laboratories all over the world were purchased, cataloged, and made available, even in the days when disposal of chemicals was becoming a major headache and expense.

James A. Moore
University of Delaware
Newark

Correction

- June 27, page 44: J. J. Thomson's name was misspelled in the book review. He discovered the electron in 1897, not 1987.

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Producers of CFC Alternatives Gear Up For 1996 Phaseout

■ ***Capacity for some CFC alternatives builds as phaseout deadline nears, but black market supply is raising serious concerns***

The summer of 1995 will be the last for chlorofluorocarbon (CFC) coolant production in the U.S. for, among other uses, automobile air conditioners and ice-cream machines.

In November 1992, the Montreal Protocol on Substances That Deplete the Ozone Layer was revised to phase out CFCs by Jan. 1, 1996. This agreement made way for hydrofluorocarbons (HFCs) and hydrochlorofluorocarbons (HCFCs) to replace CFCs in some of their uses. Alternatives plants are up and expanding, many equipment manufacturers are finalizing their switchover plans, and producers are already looking to replace the transitional HCFCs.

Decline in CFC production is not offset by gains in alternatives

Product	Net gain or loss 1992–97[a] (millions of lb)	Primary end uses affected
CFC-12	–205	Mobil air conditioners, commercial and industrial refrigeration
CFC-11	–100	Rigid polyurethane foams, commercial chillers
CFC-113	–50	Precision and electronics solvent cleaning
HFC-134a	+100	Mobil air conditioners, commercial chillers, residential refrigerators
HCFC-141b	+65	Rigid polyurethane foams
HCFC-22	+60	Unitary air-conditioning, polymer manufacture, aerosols, polystyrene foams
HCFC-123	+15	Commercial chillers
HFC-125	+10	Commercial and industrial refrigeration
HFC-152a	+10	Commercial and industrial refrigeration, aerosols

[a] Production of virgin chemical. **Source:** SRI International

Some replacements are becoming standardized: air conditioners in new cars and retrofits and compressors in home refrigerators are being switched from CFC-12 to HFC-134a, and HCFC-141b is replacing CFC-11 in polyurethane foam insulation for refrigerators. Large building cooling systems that use CFC-12 and CFC-11 are switching to HFC-134a and HCFC-123, respectively.

Meanwhile there are twists in the CFC market. With the $4.35 per lb excise tax nearly half the price of legitimate product, a "black market" in CFCs has arisen. For at least six months now, there have been reports of CFCs offered at prices below the excise tax. "It's affecting everybody's business," says Dave McDonald, product manager for fluorocarbons at LaRoche Chemicals. The black market has kept the price of CFCs down. And if unchecked, adds Craig Wien, AlliedSignal's fluorocarbons controller, it could eliminate incentives for users to switch to alternatives.

Producers speculate that the cheap CFCs are imports that have been tagged as recycled—and hence not subject to the excise tax—or mislabeled as other chemicals. Producers and the Environmental Protection Agency challenge the legitimacy of recycling claims. Says Dave Stirpe, assistant director of Alliance for Responsible Atmospheric Policy, an industry group composed of producers and users of CFCs and alternatives, "In some cases it's virgin material that's a little off-spec." There is evidence that some of the product comes from Russia. Says Stirpe, "It's hard to believe that Russia has an excess of recycled CFCs."

EPA has alerted customs officials to look for illegal imports, says Stephen R. Seidel, acting director of EPA's stratospheric protection division, and has met with the Internal Revenue Service to clarify the excise tax situation. Seidel says the issue will likely be addressed this month at a Montreal protocol working group meeting, and he adds that there are also reports of unusual imports in Europe.

Even without the competition from possibly illegal sources, CFC demand has dropped in 1994. "There's no shortage of CFCs," remarks John Bray, DuPont business manager for fluorochemicals, despite production and import allowances that are merely 25% of 1986 levels. All the U.S. producers are producing their limits, but Elf Atochem general manager for fluorocarbons Jerry Dziedzic says he expects that CFC production might slip below allowances next year. Despite the decreased demand, Seidel says there is still enough to warrant DuPont's continued production of CFCs through the end of 1995, as requested by the government (C&EN, Jan. 3, page 8).

In the alternatives arena, the newest battle is over replacements for the HCFC-22 traditionally used in household air-conditioning units. With its use to be restricted in 2010, HCFC-22 was a "secondary product," according to DuPont's development and technical service manager Helen Connon. "Now it's moved up to a higher priority." DuPont's proposed offering is Suva AC9000, a patented blend of HFC-32, -125, and -134a. AlliedSignal's AZ-50 is an azeotrope of HFC-32 and -125. Under a recent legal decision, AlliedSignal can also offer the HFC-32, -125, and -134a blend.

Commercial refrigeration "gained a lot of momentum this year" in its transition from R502 to alternatives, says AlliedSignal's Wien. Hundreds of thousands of units have been retrofitted already, and many supermarket chains have begun retrofitting plans.

The home refrigerator market is ex-

DuPont's Connon tests auto retrofit.

pected to begin the transition to alternatives this fall. It was one of the more difficult to switch because energy efficiency requirements stalled research on the new refrigerants.

The phaseout has inspired capacity buildups in HFCs and HCFCs, although they won't match CFC production at its height of 887 million lb in 1988, with 41% going to coolant use. Recycling and better leak prevention, as well as not-in-kind replacements, have reduced the market. DuPont now estimates that HCFCs and HFCs will grab only 26% of the CFC market. Some producers, DuPont's Bray adds, have halted plans to build additional alternatives plants. "The market is not as strong as was expected four years ago."

Much of the alternatives demand will be realized only when the repair service market grows. For supermarket refrigerator coolants, the service market is four times the size of the market for chemicals in new equipment; for automotive use, it is a factor of three.

AlliedSignal just started up the first phase of its newest production facility for CFC substitutes in Geismar, La., in June. Its annual capacity of 30 million lb for HFC-134a, HFC-125, HCFC-123, and HCFC-124 is to be doubled in 1996.

In the fourth quarter of 1993, LaRoche Chemicals started up its CFC alternatives plant in Gramercy, La., making 60 million lb per year of HCFC-141b and HCFC-22 combined in a swing plant. Although LaRoche has no formal plans for another plant, McDonald says the company is exploring alternatives.

The hydrofluorocarbon market is being splintered by needs for specialized mixes, according to SRI International senior consultant Rosemary Bradley, with companies offering a few dozen products. "Some products may have relatively small markets," she says, with slightly different blends for different equipment manufacturers.

HFC-134a appears to be the biggest winner, though. DuPont produces HFC-134a at Corpus Christi, Tex. Elf Atochem added equipment to increase HFC-134a capacity at its Calvert City, Ky., plant in April. ICI is doubling HFC-134a capacity at St. Gabriel, La., to 44 million lb per year through improved catalysts and plans to ramp up production to 65 million lb per year in 1996 with an even more efficient catalyst.

ICI was once a bit player in the U.S. CFC market, but now, says ICI marketing manager Dennis Berry about the move to HFC-134a, "our market share is significant, [and] we intend to stay big."

More next-generation research is focused on longer chain HFCs. Wien says AlliedSignal is looking at HFC-245 and HFC-356 for foams. But, adds Wien, as you go to longer chains, "production and process chemistry get a little more difficult and more expensive." DuPont says it is also looking at industry trends while testing fluorinated ethers and flammable hydrocarbons.

Joseph Mendelson, director of the ozone campaign at Friends of the Earth, an environmental activist group, wants to encourage research on nonfluorocarbons. "We've always looked at HFCs and HCFCs as transitional substances," he remarks. He points to hydrocarbon refrigerants that are gaining ground in Europe, but U.S. producers say manufacturers will be reluctant to use flammables because of the likelihood of litigation in case of accidents.

And EPA is addressing concerns for the fluorocarbons' global warming potential, according to Seidel. EPA already requires HFC recycling and emission controls for HFCs.

"All in all, the switchover is remarkably smooth," says Seidel. But come New Year's Day 1996, warns McDonald, "there will definitely be some crying. It won't be painless."

Elisabeth Kirschner

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FACTS & FIGURES

FOR THE CHEMICAL INDUSTRY

AT A GLANCE

1 PRODUCTION

Chemical production in the U.S. rose 3% in 1993, following a similar rise in 1992. The biggest volume commodity chemicals also posted 3% growth in output, as did thermoplastic resins. Almost all sectors showed similar steady, if unspectacular, expansion. Page 30

2 FINANCES

Sales, earnings, profitability, and return on stockholders' investment all grew last year, though sales, in particular, did so only modestly. After four years of falling income, the combined earnings of 30 major chemical firms rose 8%, well above the 2% gains in both sales and prices. Profits came by cutting costs, particularly payrolls but also capital spending. R&D budgets were unchanged from the previous year. Page 37

3 EMPLOYMENT

Companies cut their work forces in 1993, with chemical firms collectively dropping 14,000 people from their payrolls. Worst hit were workers in big companies making organics, agricultural chemicals, or plastics. The slide continued into early 1994, although there are some signs it may now be easing. Employment at drug and soap manufacturers grew in 1993. Page 54

4 MARKETS

Most major markets for chemicals posted their second year of solid growth in 1993, as the U.S. economy generally confirmed that its most recent recession was over. Demand for new homes and for cars and trucks was up strongly, thanks largely to lower interest rates. Farmers, however, did not do well, as bad weather cut crop production 14%. Page 58

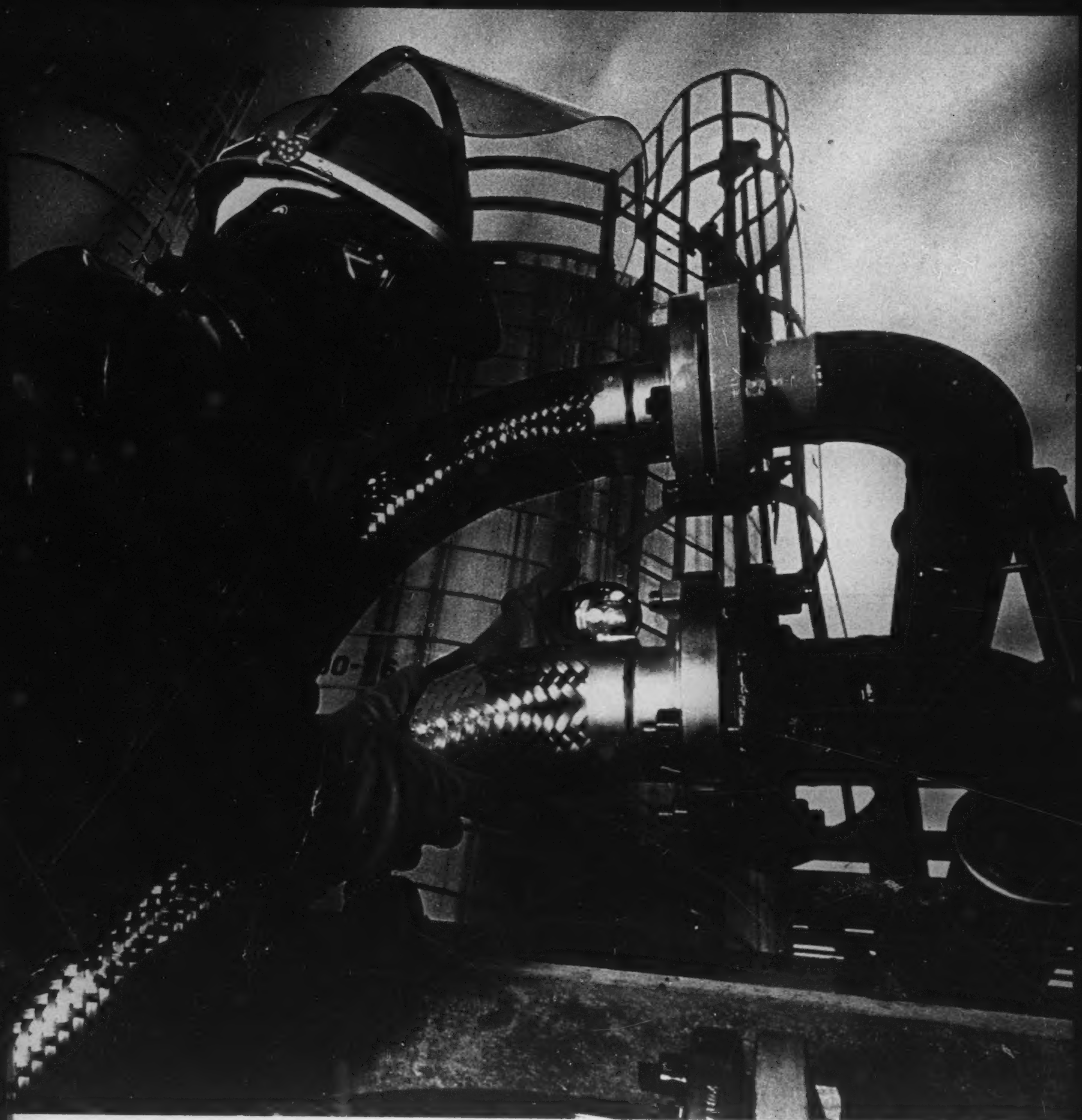
5 FOREIGN TRADE

U.S. chemical exports managed to rise a modest 2.5% in 1993, despite a U.S. economy that was strong compared with those of many of the industry's leading trading partners. But chemical imports rose faster, up 5.4%, causing the chemical trade balance, always strongly positive, to dip below $16 billion for the first time since 1989. Page 60

6 FOREIGN CHEMICAL INDUSTRIES

Cautious optimism is beginning to characterize the chemical industries in Europe and Canada as sales and earnings began to turn around last year for most of these countries. As in the U.S., job trimming was a major contributor to increased profitability. In Japan, sales slipped and earnings plummeted. For many of its less-developed Asian neighbors, however, 1993 was a strong year for chemicals, thanks to generally booming economies. Page 62

Most U.S. chemical makers were probably ready to have a year like 1993. Few would call it outstanding, certainly not when compared with the sort of growth companies were racking up year after year as recently as the late 1980s. But earnings rose substantially, particularly in the year's second half, and most other indicators of industry health—such as sales, shipments, and profitability—moved upward as well. After four years of decline when earnings for ma-



jor chemical firms fell 40% from their 1989 peak, the change was certainly welcome.

The earnings gains came, for the most part, not from stronger demand and rising prices, but through cutting costs and increasing productivity. Chemical companies that had held on to their employees through the economically lean years of the early 1990s decided in 1993 that they could no longer do so. The industry as a whole ended the year with 14,000 fewer employees than it began with, and these cuts have continued well into 1994. Job loss has been even greater at the companies that are the biggest producers of commodity chemicals. Capital spending, too, dropped 10% at the largest chemical firms last year, and even R&D budgets were held to 1992 levels.

The picture was largely the same for chemical makers in Canada and much of Europe, although changes in data collection in some of Europe's key chemical-producing nations cloud the picture there. Turnaround has been slower to reach Japan, however, where chemical profits at 12 leading companies dropped a stunning 40%.

There are signs that the belt tightening may have eased in the U.S. and the now trim chemical industry may find 1994 an even better year than 1993. Chemical sales are up in the early months of 1994, as are company earnings; job cuts have slowed; and plans, at least, call for an increase in capital spending later in the year.

1 PRODUCTION BY THE U.S. CHEMICAL INDUSTRY

Growth continues in chemical production

Production by the U.S. chemical industry grew 3% in 1993. That's the increase measured by the industry's index of production, prepared by the Federal Reserve Board. C&EN's own tally of production of the largest volume chemicals, the Top 50, shows the same 3% increase. Output by both measures grew 3% in 1992 as well, after being essentially unchanged in 1991.

Production for individual chemical categories varied widely, however. Output for organic chemicals in C&EN's Top 50 rose an overall 9%, whereas that for inorganics fell 1%. A 10% drop in production of sulfuric acid, the chemical that heads the Top 50 list, contributed much to inorganics' overall poor performance.

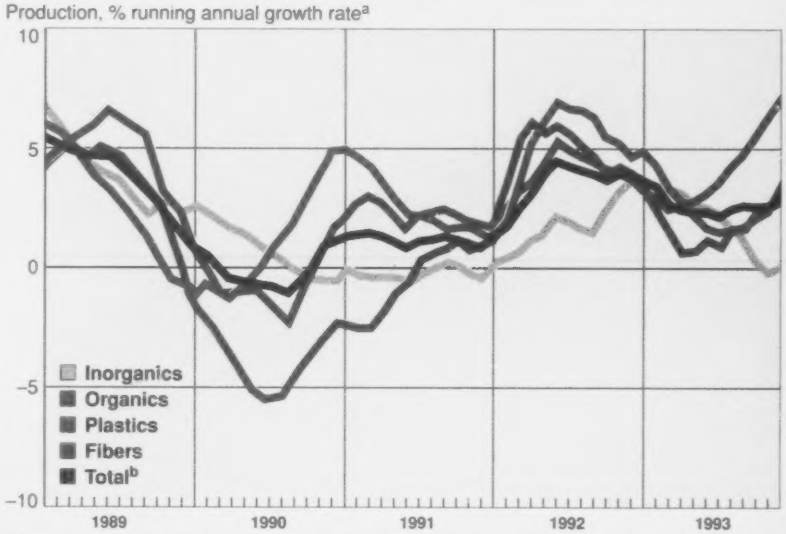
The Federal Reserve Board found output of basic chemicals, which is the board's classification for inorganics, unchanged in 1993, after a 10% rise in 1992. Production in the board's chemical products category—which includes pharmaceuticals, soaps, and paints—grew 3%, as it has annually for a decade.

As might be expected, increased use of methyl *tert*-butyl ether (MTBE) as a gasoline additive continued to send its production soaring. MTBE output more than doubled in 1993 to 24 billion lb, making it the ninth largest volume chemical. Production of MTBE precursor isobutylene rose 20% to 1.1 billion lb.

Production of phosphate rock nosedived 24% in 1993. A decline in exports of phosphate products, especially of diammonium phosphate to China, was responsible for the cutback in output, according to analysts at the Bureau of Mines. Production of diammonium phosphate fell 11% in 1993, according to data from the Fertilizer Institute. U.S. consumption of phosphate fertilizers, on the other hand, rose a healthy 6%.

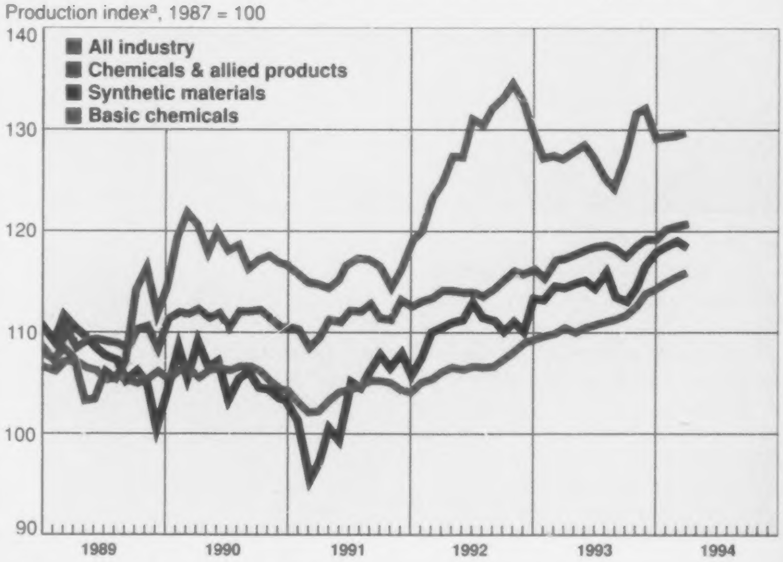
All categories of plastics posted gains in production last year. Output of thermosetting resins rose 8%, with the increase for individual resins varying from 5% for phenolics to 16% for melamines. Production of thermoplastic resins was up 3%.

All chemical sectors, except inorganics, picked up in 1993



a Average running annual growth rates in production of major plastics, inorganic and organic chemicals, and in shipments of man-made fibers. b Average running annual growth rate for products in the above four categories taken as a whole. **Sources:** International Trade Commission, Bureau of the Census, Society of the Plastics Industry, Textile Economics Bureau

Chemicals production posts modest but steady growth



a Seasonally adjusted. **Source:** Federal Reserve Board

TOP 50 CHEMICALS: Strong 9% rise in organics boosted total production 3%

Rank 1993	Rank 1992[a]		Billions of lb 1993	Billions of lb 1992
1	1	Sulfuric acid	80.31	89.72
2	2	Nitrogen	65.29	60.51
3	3	Oxygen	46.52	43.46
4	4	Ethylene	41.25	40.93
5	6	Lime[b]	36.80	35.71
6	5	Ammonia	34.50	36.59
7	8	Sodium hydroxide	25.71	24.50
8	9	Chlorine	24.06	23.51
9	19	Methyl *tert*-butyl ether	24.05	10.88
10	7	Phosphoric acid	23.04	25.58
11	10	Propylene	22.40	23.43
12	11	Sodium carbonate[c]	19.80	20.84
13	15	Ethylene dichloride	17.95	15.15
14	13	Nitric acid	17.07	16.09
15	14	Ammonium nitrate[d]	16.79	15.66
16	12	Urea[e]	15.66	17.96
17	17	Vinyl chloride	13.75	11.31
18	16	Benzene	12.32	11.98[g]
19	18	Ethylbenzene	11.76	11.11
20	19	Carbon dioxide[f]	10.69	10.88
21	23	Methanol	10.54	8.08
22	21	Styrene	10.07	9.00
23	29	Terephthalic acid[g]	7.84	5.64[g]
24	22	Formaldehyde[h]	7.61	8.28
25	25	Xylene	6.84	6.39
26	24	Hydrochloric acid	6.45	7.13
27	27	Toluene[i]	6.38	6.01[g]
28	28	*p*-Xylene	5.76	5.66
29	26	Ethylene oxide	5.68	5.83
30	30	Ethylene glycol	5.23	5.13
31	31	Ammonium sulfate	4.80	4.78
32	32	Cumene	4.49	4.67
33	34	Phenol[j]	3.72	3.71[g]
34	35	Acetic acid	3.66	3.59
35	33	Potash[k]	3.31	3.86
36	38	Propylene oxide	3.30	2.90
37	37	Carbon black	3.22	3.02
38	36	Butadiene[l]	3.09	3.23
39	40	Vinyl acetate	2.83	2.66
40	41	Titanium dioxide	2.56	2.51
41	39	Acrylonitrile	2.51	2.83
42	42	Acetone	2.46	2.43
43	44	Aluminum sulfate	2.23	2.09
44	43	Cyclohexane	2.00	2.24
45	45	Sodium silicate	1.97	1.82
46	46	Adipic acid	1.56	1.56
47	47	Sodium sulfate[m]	1.44	1.52
48	48	Calcium chloride[n]	1.40	1.39
49	49	Caprolactam	1.36	1.38
50	–	*n*-Butyl alcohol	1.33	1.26
TOTAL ORGANICS			257.38	235.24
TOTAL INORGANICS			427.95	431.18
GRAND TOTAL			685.33	666.42

a Revised. **b** Except refractory dolomite. **c** Natural and synthetic. **d** Original solution. **e** 100% basis. **f** Liquid and solid only. **g** Includes both acid and ester without double counting. **h** 37% by weight. **i** All grades. **j** Synthetic only. **k** K_2O basis. **l** Rubber grade. **m** High and low purity. **n** 75% basis, solid and liquid.

PRODUCTION: Drugs and medicines rose, paints and some inorganics declined

Industrial production indexes, 1987 = 100	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	% annual change 1992–93	% annual change 1983–93
Total index	84.9	92.8	94.4	95.3	100.0	104.4	106.1	106.0	104.1	106.5	110.9	4%	3%
Manufacturing, total	80.9	89.3	91.6	94.3	100.0	104.7	106.4	106.1	103.7	106.8	111.7	5	3
Nondurable manufacturing	87.0	90.8	91.5	94.9	100.0	102.3	103.7	104.4	103.5	106.5	108.7	2	2
Chemicals & products	87.5	91.4	91.4	94.6	100.0	106.0	109.2	111.8	111.4	114.3	117.8	3	3
Chemicals & synthetic materials	88.6	92.8	92.2	93.9	100.0	107.5	112.2	114.5	111.3	114.8	118.6	3	3
Basic chemicals	92.1	96.9	96.1	95.1	100.0	104.7	108.4	118.9	116.0	128.0	128.1	0	3
Alkalies & chlorine	87.9	95.3	93.6	92.1	100.0	104.9	107.4	107.2	104.2	105.4	108.4	3	2
Inorganic pigments	87.3	89.0	95.1	96.2	100.0	111.4	114.0	109.0	101.5	118.2	116.3	–2	3
Inorganic chemicals, nec	94.3	98.0	97.2	94.7	100.0	103.5	107.7	123.8	120.0	133.6	131.4	–2	3
Industrial organic chemicals	89.9	93.4	94.1	95.1	100.0	111.6	117.8	119.4	115.7	111.6	117.0	5	3
Synthetic materials[a]	84.3	88.9	86.9	91.6	100.0	104.3	107.7	105.8	102.9	110.2	114.6	4	3
Plastics materials	74.4	81.1	84.1	88.2	100.0	104.0	106.1	106.7	101.5	108.2	112.4	4	4
Man-made fibers	92.3	93.3	86.6	93.7	100.0	103.5	110.5	102.8	103.3	110.1	114.6	4	2
Chemical products	86.6	89.0	90.2	95.9	100.0	104.7	106.3	108.8	110.9	113.1	116.4	3	3
Drugs & medicines	86.1	86.9	88.5	96.7	100.0	104.9	108.6	112.6	120.6	127.2	134.8	6	5
Soaps & toiletries	91.4	90.6	91.3	96.7	100.0	106.4	107.3	109.4	108.4	106.4	106.7	0	2
Paints	84.6	91.8	95.7	97.5	100.0	103.8	98.9	97.1	91.0	90.6	87.8	–3	0
Agricultural chemicals	87.5	102.0	96.1	88.5	100.0	106.5	115.3	119.3	116.2	122.0	125.8	3	4
Petroleum products	89.6	92.8	92.6	98.9	100.0	101.9	102.3	103.3	101.6	102.7	104.9	2	2
Rubber & plastics products	74.3	83.8	85.8	90.8	100.0	102.6	106.0	107.2	104.5	110.8	115.9	5	5

a Includes synthetic rubber. **nec** = not elsewhere classified. **Source:** Federal Reserve Board

ORGANIC CHEMICALS: Output was up in more cases than down in 1993

Millions of lb unless otherwise noted	Production											% annual change	
	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993[a]	1992–93	1983–93
Acetic acid, synthetic	2,807	2,619	2,897	2,728	3,246	3,159	3,294	3,751	3,615	3,594	3,656	2%	3%
Acetone	1,859	1,862	1,788	1,910	1,846	2,303	2,524	2,329	2,347	2,435	2,462	1	3
Acrylonitrile	2,035	2,146	2,219	2,349	2,182	2,452	2,609	2,676	2,647	2,829	2,508	–11	2
Aniline	663	786	716	824	829	1,029	1,016	989	996[a]	1,009	1,011	0	4
Benzene, mg[b,c]	1,232	1,318	1,283	1,362	1,575	1,608	1,631	1,699	1,569	1,636[a]	1,677	3	3
Bisphenol A	643	762	949	956	1,000	1,340	1,241	1,149	1,181[a]	1,197	1,286	7	7
1,3-Butadiene[d]	2,353	2,452	2,340	2,546	2,931	3,169	3,121	3,088	3,054	3,232	3,092	–4	3
1-Butanol	833	908	716	881	1,155	1,194	1,751	1,269	1,320	1,279	1,328	4	5
Caprolactam	977	1,027	1,089	1,109	1,156	1,261	1,307	1,379	1,284	1,377	1,359	1	3
Carbon tetrachloride	573	713	646	627	672	761	na	413	315	na	na	—	—
Chloroform	362	405	275	422	462	524	588	484	505	na	476	—	3
Cumene	3,345	3,754	2,627	3,745	4,105	4,455	4,426	4,311	4,284[a]	4,666	4,489	–4	3
Cyclohexane	1,656	1,994	1,657	2,070	2,276	2,297	2,273	2,460	2,307	2,242	2,000	–11	1
Dioctyl phthalate	300	301	275	296	343	344	306	310	270	270	245	–9	–2
Ethanol, synthetic	1,077	1,060	649	529	574	562	549	546	526	698	740	6	–4
Ethanolamines[e]	468	504	537	543	627	608	667	727	658	694[a]	706	2	4
Ethylbenzene	7,876	7,562	7,386	9,020	9,346	9,929	9,235	8,369	11,446[a]	11,108	11,758	6	4
Ethyl chloride	282	290	171	164	155	152	162	149	na	na	na	—	—
Ethylene	28,680	31,383	29,847	32,859	34,951	37,204	34,988	36,467	39,955	40,924	41,244	1	4
Ethylene dichloride	11,506	10,710	12,101	12,940	12,197	13,028	13,383	13,849	13,713	15,150	17,945	18	5
Ethylene glycol	4,425	4,823	4,178	4,771	5,183	5,517	5,461	5,070	4,809	5,128	5,228	2	2
Ethylene oxide	5,534	5,699	5,430	5,430	4,785	5,953	5,031	5,355	5,248	5,829	5,684	2	2
2-Ethylhexanol	387	541	536	571	662	743	612	650	657	692	688	–1	6
Formaldehyde, 37%[f]	5,465	5,815	5,606	5,549	5,733	6,280	5,893	6,720	6,612	8,278	7,604	–8	4
Isobutylene	760	883	na	1,124	1,035	1,244	1,193	1,212	972	952	1,146	20	4
Isopropyl alcohol	1,209	1,394	1,235	1,301	1,371	1,389	1,474	1,456	1,342	1,463	1,236	–15	0
Maleic anhydride	299	359	394	359	382	448	475	424	381	436	424	–3	4
Methanol, synthetic	7,982	8,186	5,003	7,205	7,537	8,142	8,167	8,344	8,704	8,082	10,542	30	3
Methyl *tert*-butyl ether	839	1,376	1,891	3,375	3,514	5,680	8,227	8,884	9,570[g]	10,877[g]	24,053[g]	121	40
Methyl chloride	409	482	410	605	373	597	461	772	916	966	849	–12	8
Methyl ethyl ketone	531	543	537	600	672	482	450	465	513	479	556	16	1
Methyl methacrylate	844	917	858	943	1,029	1,100	1,161	1,182	1,102	1,208	1,088	–10	3
Methylchloroform	586	675	869	652	694	724	783	803	644	692	452	–35	–3
Methylene chloride	584	607	467	566	516	504	482	461	389	362	354	–2	–5
Perchloroethylene	547	573	678	414	473	498	481	372	239	245	271	11	–7
Phenol, synthetic[h]	2,638	2,889	2,841	3,115	3,351	3,562	3,806	3,538	3,484[a]	3,707[a]	3,718	0	3
Phthalic anhydride	838	870	820	863	1,035	999	917	940	874[a]	898	854	–5	0
Propylene[i]	13,959	15,559	14,887	16,522	19,019	21,224	20,571	21,846	21,549	23,421	22,398	4	–5
Propylene glycol	484	462	500	573	747	840	805	754	666	509	885	74	6
Styrene	6,802	7,709	7,622	7,888	8,014	8,984	8,337	8,017	9,003[a]	9,000	10,063	–12	4
Terephthalic acid, dimethyl ester[j]	5,626	5,912	6,490	6,257	7,601	10,234	8,426	7,773	7,654[a]	5,637[a]	7,837	–28	3
Toluene, mg[b,k]	780	728	698	611	967	892	806	861	873	833[a]	833	6	1
Vinyl acetate	1,963	2,024	2,112	1,710	1,813	2,561	2,552	2,659	2,732	2,657	2,827	6	4
Vinyl chloride	6,875	6,084	9,463	8,439	8,402	9,058	10,135	10,623	11,142	11,307	13,746	–22	7
***o*-Xylene**	781	688	675	788	940	971	983	943	935[a]	918	884	–4	1
***p*-Xylene**	4,114	4,264	4,779	5,035	5,155	5,601	5,344	5,200	5,431[a]	5,656	5,757	2	3

Note: In 1992, the International Trade Commission changed its format for presenting revised data in its annual synthetic organic chemicals report to conform to the format of the Harmonized Tariff Schedule (HTS) of the U.S. For this reason, revised data for 1992 for some organic chemicals—in this table benzene, phenol, terephthalic acid, and toluene—are not comparable with either revised data for previous years or preliminary data for 1993. Thus, preliminary data for 1992, which are comparable, are reported for these chemicals. **mg** = millions of gallons. **a** Preliminary, calculated from quarterly data. **b** Tar distillers and coke-oven operators not included. **c** Specification grades. **d** Rubber grade. **e** Mono-, di-, and triethanolamines. **f** By weight. **g** C&EN estimate. **h** Does not include data for coke ovens and gas-retort ovens. **i** All grades. **j** Includes both acid and dimethyl ester (DMT), without double counting. **k** All grades, includes material used in blending motor fuel. **na** = not available. **Source:** International Trade Commission

INORGANIC CHEMICALS: Largest volume product, sulfuric acid, fell 10% in year of mixed results

Thousands of tons unless otherwise noted	Production											% annual change	
	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993[a]	1992–93	1983–93
Aluminum sulfate[b]	1,119	1,129	1,268	1,222	1,227	1,237	1,243	1,227	1,185	1,047	1,113	6%	0%
Ammonia, 100%[c,d]	14,072	16,692	17,319	14,487	16,098	16,821	16,468	17,003	17,169	18,295	17,252	–6	2
Ammonium nitrate, 100%[e]	6,240	7,146	7,149	6,091	6,547	7,504	7,871	7,713	7,819	7,832	8,394	7	3
Ammonium sulfate, 100%[f]	1,956	2,067	2,093	2,080	2,189	2,333	2,384	2,519	2,243	2,391	2,398	0	2
Chlorine gas[g]	9,960	10,700	10,402	10,436	11,078	11,257	11,413	11,809	11,421	11,757	12,028	2	2
Hydrochloric acid, 100%[h]	2,468	2,732	2,807	2,413	2,996	3,228	3,268	3,140	3,301	3,567	3,224	–10	3
Hydrogen, bcf, 100%[i,j]	103	109	121	136	173	177	146	148	153	161	178	11	6
Hydrogen peroxide, 100%[k]	117	139	144	152	153	168	204	238	254	na	na	na	na
Nitric acid, 100%[k]	6,768	7,726	7,631	6,734	7,225	7,991	8,349	7,932	7,927	8,043	8,537	6	2
Nitrogen gas, bcf, 100%[i,l]	560	661	665	677	685	722	744	749	770	835	901	8	5
Oxygen, bcf, 100%[i,j]	346	375	393	383	405	452	460	462	470	525	562	7	5
Phosphoric acid, 100% P_2O_5	9,767	11,370	10,607	9,578	10,599	11,659	11,737	12,035	12,109	12,792	11,521	–10	2
Phosphorus[m]	366	386	359	364	344	343	353	346	306	271	267	–1	–3
Sodium chlorate, 100%	323	295	259	267	289	267	290	327	449	554	544	–2	5
Sodium hydroxide, 100%	10,039	10,914	10,811	10,691	11,553	10,533	11,470	12,030	11,713	12,249	12,854	5	3
Sodium phosphate[n]	669	675	625	617	586	549	610[o]	497	462	na	na	na	na
Sodium silicate[p]	710	685	692	791	952	812	833	816	870	912	983	8	3
Sodium sulfate, 100%[q]	914	901	1,203	837	799	819	755	786	794	761	718	–6	–2
Sulfuric acid, 100%[r]	36,583	41,802	39,890	35,993	39,256	42,580	43,301	44,337	43,466	44,860	40,153	–10	1
Titanium dioxide, 100%[s]	760	835	860	931	968	1,022	1,101	1,077	1,095	1,253	1,280	2	5
Urea	6,137	7,433	6,975	6,264	7,433	7,914	8,004	8,216	8,133	8,981	7,832	–13	2

Note: bcf = billions of cubic feet. **a** Preliminary. **b** Commercial, 17% Al_2O_3, includes municipalities. **c** Synthetic anhydrous. **d** Excludes by-product ammonia liquor and ammonium sulfate. **e** Original solution. **f** Synthetic and noncoke by-product. **g** Includes quantities liquefied for use, storage, or shipment. **h** Includes anhydrous hydrochloric acid production. **i** High- and low-purity gas. **j** Liquid and gas; excludes amounts vented and used as fuel, and amounts produced in petroleum refineries for captive use. **k** Includes unspecified amounts produced but not withdrawn from the system. **l** Excludes amounts produced and consumed in making synthetic ammonia or ammonia derivatives. **m** Elemental, white (yellow), and red (technical). **n** Tripolyphosphate (100% $Na_5P_3O_{10}$). **o** Includes tetrabasic (pyro) phosphate. **p** Soluble silicate glass (water glass), solid and liquid (anhydrous); excludes amounts produced and consumed in making meta-, ortho-, and sesquisilicates. **q** Anhydrous, high and low purity, and Glauber's salt. **r** Gross (new and fortified). **s** Composite and pure. **na** = not available. **Sources:** Department of Commerce, Bureau of the Census

MINERALS: Phosphate rock production tumbled 24%, potash output dropped 12%

Thousands of tons	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993[a]	% annual change 1992–93	% annual change 1983–93
Bromine, sold or used[b]	185	193	160	155	168	180	193	195	187	183	185	1%	0%
Calcium chloride, production[c]	912	1,036[d]	940	780	658	677	628[d]	691[d]	620[d]	821[d]	na	na	na
Lime, production[e]	14,867	15,922	15,690	14,474	15,733	17,052	17,152	17,452	17,270[d]	17,857	18,427	3	2
Lithium, consumption[d,f]	2.2	3.2	2.5	2.6	2.6	3.0	3.0	3.0	2.9	2.5	2.8	12	2
Phosphate rock													
Production	46,928	54,230	56,035	44,445	45,144	50,032	54,913	51,084	53,016	51,770	39,125	–24	–2
Exports	13,239	12,707	10,071	8,651	9,319	8,920	8,644	6,876	5,602	4,104	3,525	–14	–12
Potash (K_2O equivalent)[g]													
Production	1,575	1,724	1,429	1,325	1.391	1,677	1,758	1,888	1,928	1,879	1,653[d]	–12	0
Imports	4,894	5,323	5,063	4,643	4,490	4,648	3,758	4,590	4,990	4,683	4,809[d]	3	0
Apparent consumption[h]	6,231	6,638	5,893	5,338	5,609	5,803	4,960	6,011	6,186	5,898	5,988[d]	2	0
Sodium carbonate, production[i]	8.467	8,511	8,511	8,438	8,891	9,632	9,915	10,093	9,926	10,338	9,878	–4	2
Sulfur, production[j]	10,240	11,742	12,797	12,221	11,616	11,845	12,778	12,743	11,928	11,759	11,684[d]	–1	1
Recovered elemental	5,462	5,747	5,857	6,411	6,791	7,103	7,176	7,205	7,326	7,769	7,826[d]	1	4
Frasch	3,530	4,622	5,524	4,457	3,530	3,499	4,286	4,107	3,162	2,557	2,425[d]	–5	–4
Other production	1,249	1,372	1,416	1,354	1,296	1,243	1,316	1,431	1,440	1,433	1,433[d]	0	1
Apparent consumption[h]	12,112	13,976	13,192	11,669	12,481	14,012	13,983	14,392	14,255	14,056	13,889[d]	–1	1

a Preliminary data, except those for phosphate rock. **b** Elemental bromine sold as such or used in preparation of bromine compounds by primary producers. **c** 75% $CaCl_2$ equivalent. **d** Estimated. **e** Sold or used by producers for commercial or captive use. Produced from limestone and dolomite, does not include amount regenerated by paper industry; excludes Puerto Rican production. **f** Lithium content basis. **g** Includes muriate and sulfate of potash, potassium magnesium sulfate, and parent salts; excludes other chemical compounds containing potassium. **h** Calculated from shipments plus imports minus exports. **i** Natural and synthetic until 1986, natural only in 1987–92. **j** Sulfur content basis. **na** = not available. **Sources:** Bureau of Mines, Bureau of the Census

PLASTICS: Strong year for thermosets, thermoplastics gain as well

Millions of lb[a]	Production											% annual change	
	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1992–93	1983–93
THERMOSETTING RESINS													
Epoxy[b]	334	406	385	398	433	486	509	499	497	457	510	12%	4%
Melamine	180	210	192	173	212	207	222	202	196	232	270	16	4
Phenolic[c,d]	2,477	2,502	2,621	2,735	2,869	3,066	2,879	2,946	2,658	2,923	3,078	5	2
Polyester[e]	1,084	1,232	1,223	1,271	1,367	1,404	1,319	1,221	1,075	1,175	1,264	8	2
Urea	1,172	1,199	1,210	1,271	1,382	1,425	1,477	1,496	1,483	1,548	1,743	13	4
TOTAL	**5,247**	**5,549**	**5,631**	**5,848**	**6,263**	**6,588**	**6,408**	**6,364**	**5,909**	**6,335**	**6,865**	**8%**	**3%**
THERMOPLASTIC RESINS													
Polyethylene													
Low density[f]	8,041	8,413	8,889	8,903	9,599	10,397	9,695	11,148	11,582	11,917	12,044	1%	4%
High density[g]	5,689	6,085	6,671	7,182	7,995	8,400	8,102	8,337	9,213	9,808	9,912	1	6
Polypropylene	4,433	4,940	5,139	5,812	6,647	7,274	7,238	8,310	8,330	8,421	8,614	2	7
Styrene polymers													
Polystyrene	3,570	3,838	4,054	4,470	4,780	5,187	5,104	5,021	4,954	5,096	5,367	5	4
Styrene-acrylonitrile	93	99	87	92	126	148	113	135	109	113	105	–7	1
Acrylonitrile-butadiene-styrene and other styrene polymers[h]	1,889	2,127	2,036	2,196	2,254	2,418	2,394	2,351	2,287	2,610	2,920	12	4
Polyamide, nylon type	321	396	399	465	507	566	569	558	576	668	768	15	9
Polyvinyl chloride and copolymers	6,067	6,760	6,772	7,256	7,971	8,350	8,478	9,096	9,164	9,989	10,257	3	5
Thermoplastic polyester	778	899	965	1,175	1,394	1,652	1,630	1,879	2,115	2,413	2,536	5	12
TOTAL	**30,881**	**33,557**	**35,012**	**37,551**	**41,273**	**44,392**	**43,323**	**46,835**	**48,330**	**51,035**	**52,524**	**3%**	**6%**

Note: Totals are for those products listed and exclude some small-volume plastics. **a** Dry-weight basis unless otherwise specified. **b** Unmodified. **c** Includes other tar-acid resins. **d** Gross-weight basis. **e** Unsaturated. **f** Density 0.940 and below. **g** Density above 0.940. **h** Includes styrene-butadiene copolymers and other styrene-based polymers. **Source:** Society of the Plastics Industry

SYNTHETIC RUBBER: Shipments rose 3% in 1993, continuing previous year's upswing

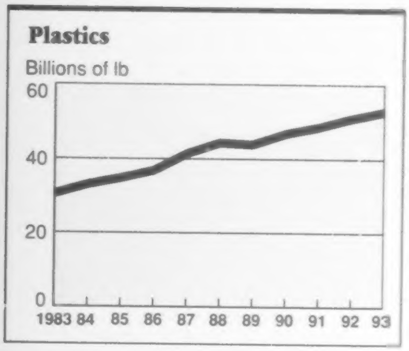
Thousands of metric tons	Shipments[a]											% annual change	
	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1992–93	1983–93
Styrene-butadiene rubber	881	888	753	736	847	829	827	791	727	796	817	3%	–1%
Polybutadiene	391	433	392	384	414	430	427	431	416	463	473	2	2
Ethylene-propylene	155	185	174	188	205	224	225	208	192	206	227	10	4
Nitrile-solid	56	65	58	64	72	75	72	69	71	74	78	5	3
Polychloroprene	88	93	82	82	81	82	79	79	70	72	70	–3	–2
Other[b]	303	323	289	310	336	355	295	329	298	315	328	4	1
TOTAL	**1,874**	**1,987**	**1,748**	**1,764**	**1,955**	**1,995**	**1,925**	**1,907**	**1,774**	**1,926**	**1,993**	**3%**	**1%**

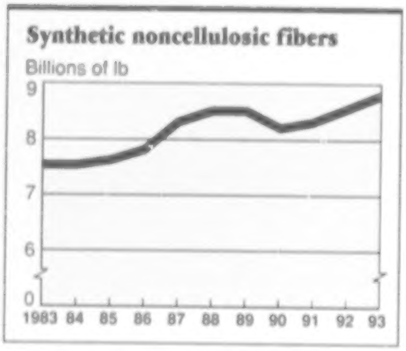
a Includes Canada. **b** Includes butyl styrene-butadiene rubber latex, nitrile latex, polyisoprene, and miscellaneous others. **Source:** International Institute of Synthetic Rubber Producers

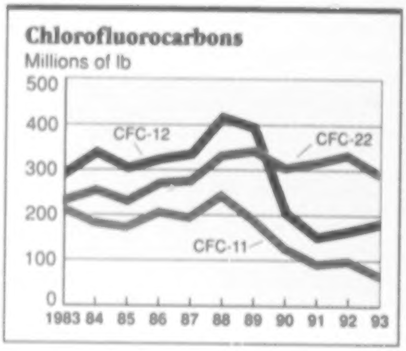
SYNTHETIC FIBERS: Nylon, olefin posted healthy gains, acrylic fell for ninth consecutive year

Millions of lb	Production											% annual change	
	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1992–93	1983–93
NONCELLULOSIC FIBERS													
Acrylic[a]	671	671	631	616	592	588	543	506	454	439	433	–1%	–4%
Nylon	2,419	2,412	2,343	2,514	2,689	2,669	2,740	2,662	2,535	2,556	2,664	4	1
Olefin[b]	906	997	1,249	1,393	1,494	1,588	1,639	1,822	1,866	2,002	2,138	7	2
Polyester	3,544	3,392	3,341	3,305	3,541	3,681	3,594	3,195	3,411	3,576	3,557	–1	0
CELLULOSIC FIBERS													
Acetate[c]	229	199	558	619	605	614	580	505	486	495	505	2	–2
Rayon	401	421											
TOTAL	**8,168**	**8,092**	**8,122**	**8,447**	**8,921**	**9,140**	**9,096**	**8,690**	**8,752**	**9,068**	**9,297**	**3%**	**1%**

a Includes modacrylic. **b** Includes olefin yarn and monofilaments and olefin and vinyon staple, tow, and fiberfill. **c** Includes diacetate and triacetate; excludes production for cigarette filters.
Source: Fiber Economics Bureau







PAINTS AND COATINGS: Shipments for architectural uses grew fastest in year of steady expansion

Millions of gal	Shipments											% annual change	
	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993[a]	1992-93	1983-93
Architectural	433	457	478	498	527	536	537	557	538	562	586	4%	3%
Product[b]	294	336	352	368	340	364	360	346	320	334	342	2	2
Special purpose	130	145	145	135	146	154	179	197	180	169	172	2	3
TOTAL	**857**	**938**	**975**	**1,001**	**1,013**	**1,054**	**1,076**	**1,100**	**1,038**	**1,065**	**1,100**	**3%**	**3%**

a Calculated from quarterly data. b For original equipment manufacturers. **Source:** Department of Commerce

AEROSOLS: Production decreased 2% in 1993 as volume fell for many end uses

Millions of units	Production[a]											% annual change	
	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1992-93	1983-93
Personal products	747	832	879	952	964	1,100	1,015	1,050	905	990	930	-6%	2%
Household products	586	603	630	635	640	650	680	680	690	695	738	6	2
Automotive & industrial products	303	337	342	375	379	440	475	415	450	455	420	-8	3
Paints and finishes	300	307	290	297	307	331	350	350	350	380	390	3	3
Insect sprays	180	184	190	193	190	190	197	190	200	200	207	4	1
Food products	132	138	140	136	140	157	175	175	192	190	205	8	-4
Animal products	19	16	15	22	22	8	8	8	8	8	6	-25	-11
Miscellaneous	15	15	23	18	80	31	12	15	19	71	44	-38	11
TOTAL	**2,282**	**2,432**	**2,509**	**2,628**	**2,722**	**2,907**	**2,912**	**2,883**	**2,814**	**2,989**	**2,940**	**-2%**	**3%**

a Includes Puerto Rican production. **Source:** Chemical Specialties Manufacturers Association

CHLOROFLUOROCARBONS: CFC-12 rose 13% as other nonhydrogenated products dropped

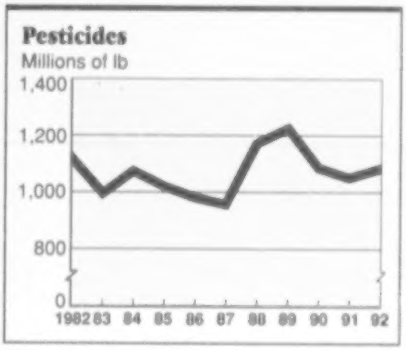
Millions of lb	Production											% annual change	
	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993[a]	1992-93	1983-93
Chlorodifluoromethane (CFC-22)	236	254	235	271	275	333	343	306	314	330	291	-12%	2%
Dichlorodifluoromethane (CFC-12)	290	337	302	322	335	414	392	209	157	163	185	13	-4
Trichlorofluoromethane (CFC-11)	215	185	176	202	198	249	192	135	99	100[a]	72	-28	-10
All other fluorinated hydrocarbons[b]	279	337	306	344	354	379	385	na	239	na	na	—	—
TOTAL	**1,020**	**1,113**	**1,019**	**1,139**	**1,162**	**1,374**	**1,312**	**na**	**809**	**na**	**na**	—	—

a Preliminary. b Includes other fluorohalogenated hydrocarbons. **na** = not available. **Source:** International Trade Commission

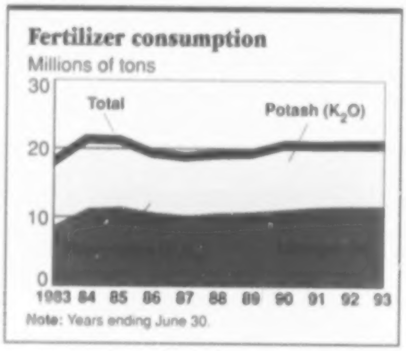
PESTICIDES: Herbicides and insecticides production recovered in 1992

Millions of lb	Production 1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	% annual change 1991–92	1982–92
Herbicides	734	587	688	647	625	623	676	676	643	657	696	6%	−1%
Insecticides	229	206	211	213	204	185	203	208	264[a]	181	190	5	−2
Nematicides	71[b]	76[b]	53[b]	50[b]	66	76	85	112	67[b]	72	71[b]	−1	0
Fungicides	77	43	78	75	70	62	193[a]	207[a]	85	na	85	—	1
Plant growth regulators	9[b]	5[b]	8	8	5	2[b]	4	5[b]	6[b]	17	12	−3	—
TOTAL[c]	**1,137**	**975**	**1,074**	**1,014**	**982**	**964**	**1,183**[a]	**1,222**[a]	**1,093**[a]	**1,054**	**1,083**	**3%**	**0%**

a These seemingly anomalous values have been verified by the source. **b** Does not include production intended for sale outside the U.S., which is included in annual total. **c** Includes miscellaneous other pesticides and, in some cases, production, usually intended for sale outside the U.S., not reported by subcategory. **na** = not available.
Source: National Agricultural Chemicals Association



Pesticides
Millions of lb



Fertilizer consumption
Millions of tons

Note: Years ending June 30.

FERTILIZER CONSUMPTION: Use of phosphates grew substantially last year

Thousands of tons	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	% annual change 1992–93	1983–93
Nitrogen (N)	9,127	11,092	11,493	10,424	10,210	10,512	10,593	11,076	11,287	11,446	11,358	−1%	2%
Phosphates (P_2O_5)	4,138	4,901	4,658	4,178	4,008	4,129	4,117	4,345	4,201	4,218	4,458	6	1
Potash (K_2O)	4,831	5,797	5,553	5,053	4,837	4,973	4,838	5,203	5,001	5,042	5,110	1	1
TOTAL	**18,096**	**21,790**	**21,704**	**19,655**	**19,055**	**19,614**	**19,548**	**20,624**	**20,489**	**20,706**	**20,926**	**1%**	**1%**

Note: Years ending June 30. **Source:** Fertilizer Institute

FERTILIZER PRODUCTION: Phosphate rock plunged 24% in dismal year for major products

Thousands of tons	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	% annual change 1992–93	1983–93
NITROGEN PRODUCTS													
Ammonia	13,361	16,613	16,594	12,565	13,357	14,136	14,052	14,446	13,790	13,309	12,587	−5%	−1%
Ammonium nitrate	3,232	3,365	3,178	2,250	2,472	2,765	2,703	2,579	2,551	2,487	2,700	9	−2
Ammonium sulfate	1,969	2,078	2,343	2,058	2,153	2,260	2,327	2,460	2,195	2,342	2,379	2	2
Urea	4,112	4,889	3,975	3,564	4,253	4,501	4,430	4,287	4,241	4,164	3,863	−7	−1
PHOSPHATE PRODUCTS													
Diammonium phosphate	10,264	12,358	10,800	7,492	9,537	11,575	13,160	13,226	13,573	14,119	12,635	−11	2
Monoammonium phosphate	1,423	1,654	1,641	1,416	1,679	1,818	1,862	2,252	2,227	2,342	2,693	15	7
Concentrated superphosphate	2,684	2,404	2,570	2,127	2,049	2,032	1,777	1,988	1,914	2,074	na	—	—
Phosphate rock	40,664	47,465	49,348	36,227	39,330	42,220	47,676	44,269	44,877	45,941	34,800	−24	−2
Phosphoric acid (P_2O_5)	9,182	10,899	9,837	8,085	8,903	10,234	10,742	11,036	10,934	11,354	10,348	−9	1
POTASH PRODUCTS													
Potassium chloride	1,928	2,168	1,713	1,715	1,810	2,243	2,316	2,351	2,387	2,337	1,927	−18	0

Note: Figures are based on Fertilizer Institute surveys and may not represent the entire industry. **na** = not available. **Source:** Fertilizer Institute

Chemical industry begins to recover

At last, the U.S. chemical industry has had a reasonable year. Although 1993 will not go down in history as a particularly good year for chemical makers, it was the first year since 1988 in which the industry increased earnings over the previous year. Earnings and profitability are nowhere near the levels they were in the late 1980s, but the industry once again appears to be growing.

The upward move came after four years of sagging performance for the industry during which earnings plummeted more than 40% and various measures of profitability fell dramatically. The result was a massive contraction of chemical employment and cuts in capital spending. The reason for capital spending cuts was easy to see—major markets had turned down, so there was no need to increase production capacity.

Now, however, many of these same markets are growing once again: Motor vehicles and housing, both big users of chemical products, are prime examples. As a result, chemical companies in 1993 began to see business increase. Since these companies have spent the past few years cutting costs, especially in white-collar employment, earnings were high. For instance, in 1993, sales increased only about 2% for the 30 major chemical companies C&EN regularly monitors, while earnings rose a much greater 8%. Thanks to the earnings increase, profit margins for the group rose to 5.3% from 5% in 1992, and return on stockholders equity increased to 12.4% from 12.0%.

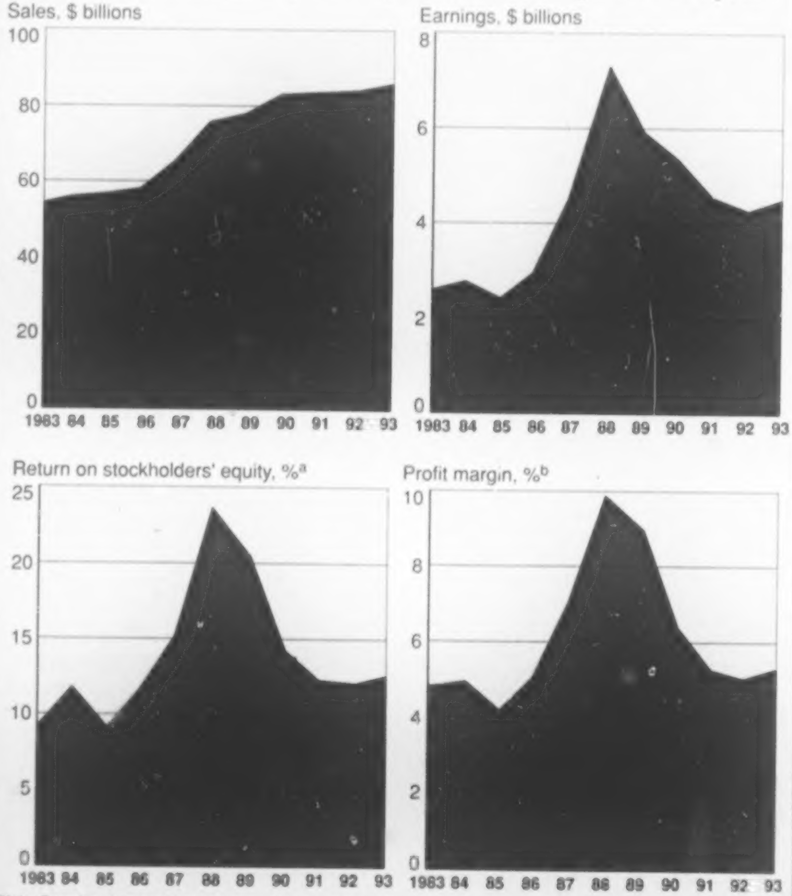
Further evidence that the earnings growth was caused as much by cutting costs as by growing markets can be found in several other measures of industry performance. Shipments of chemicals and allied products increased just 4% for the year, and demand for industrial chemicals rose only 3%. Pricing was anything but good. The government's producer price index for chemicals and allied products increased 2% from the year before, but most of this increase came from drugs and pharmaceuticals, up 5% for the year. Other more basic chemical sectors showed little or no change.

However, these lackluster indicators are not necessarily bad news for the industry's future. If chemical companies can manage an average 8% earnings increase with the price and demand situations that prevailed in 1993, all they need is to have a small rise in prices to begin reaping greater returns.

In fact, Wall Street's financial community is betting on better days to come. Chemical stock prices set new record highs in 1993 and continue to rise this year, indicating that investors believe there is still plenty of room for improvement in the chemical industry.

But there are danger signals for a chemical recovery. Chief among these are interest rate increases that may slow demand for housing and automobiles. The recent decline of the dollar may force further rate increases as the U.S. tries to bolster its currency and fight inflation coming from higher priced imports.

Earnings, profitability finally started to improve last year



Note: Based on data for 30 major chemical companies. a After-tax earnings as a percentage of year-end stockholders' equity. b After-tax earnings as a percentage of sales.

TOP 100 CHEMICAL PRODUCERS: **Most of the largest companies saw big gains in profits in 1993**

Rank 1993	1992		Chemical sales 1993 ($ millions)	Change from 1992	Chemical sales as % of total sales	Industry classification	Chemical operating profits[a] ($ millions)	Change from 1992	Chemical operating profits as % of total profits	Operating profit margin[b]	Identifiable chemical assets ($ millions)	Chemical assets as % of total assets	Operating return on chemical assets[c]
1	1	**DuPont**	$15,603	0.4%	42.1%	Diversified	$750	–45.9%	51.7%	4.8%	$13,957	45.1%	5.4%
2	2	**Dow Chemical**	12,524	–3.1	69.3	Basic chemicals	773	30.6	53.7	6.2	12,530	49.1	6.2
3	3	**Exxon**	10,024	–5.7	9.2	Petroleum	638	–3.3	7.6	6.4	8,478	10.1	7.5
4	4	**Hoechst Celanese**	6,347	–2.3	92.0	Basic chemicals	561	26.9	155.8	8.8	na	na	na
5	5	**Monsanto**	5,651	5.0	71.5	Basic chemicals	731	17.5	90.2	12.9	5,312	61.5	13.8
6	7	**General Electric[d]**	5,042	3.9	8.3	Diversified	834	12.7	12.7	16.5	8,181	3.3	10.2
7	6	**Union Carbide**	4,640	–4.8	100.0	Basic chemicals	354	12.0	100.0	7.6	4,419	100.0	8.0
8	8	**Occidental Petroleum**	4,065	–3.8	47.6	Petroleum	184	100.0	84.8	4.5	5,780	33.8	3.2
9	9	**BASF**	4,037	–0.3	77.6	Basic chemicals	na	na	na	na	na	na	na
10	10	**Eastman Chemical**	3,903	2.4	100.0	Basic chemicals	476	–5.7	100.0	12.2	4,341	100.0	11.0
11	14	**Shell Oil**	3,875	18.2	18.6	Petroleum	328	89.6	23.0	8.5	4,312	16.1	7.6
12	12	**Amoco**	3,773	2.2	13.2	Petroleum	321	def	10.5	8.5	3,938	13.8	8.5
13	—	**ICI Americas**	3,565	20.0	100.0	Basic chemicals	188	45.7	100.0	5.3	na	na	na
14	11	**Mobil**	3,533	–4.6	5.5	Petroleum	25	–82.4	0.5	0.7	3,451	8.5	0.7
15	16	**Rohm and Haas**	3,269	6.7	100.0	Basic chemicals	267	–21.9	100.0	8.2	3,200	100.0	8.3
16	15	**Arco Chemical**	3,192	3.0	100.0	Basic chemicals	425	–7.0	100.0	13.3	3,502	100.0	12.1
17	19	**Miles**	3,053	4.7	47.3	Diversified	na	na	na	na	na	na	na
18	18	**Air Products[e]**	2,906	3.6	87.3	Basic chemicals	417	–16.6	113.0	14.3	3,646	87.5	11.4
19	13	**W. R. Grace**	2,895	–16.7	65.7	Specialty chemicals	392	–9.9	103.2	13.5	2,115	39.5	18.5
20	21	**AlliedSignal**	2,791	7.3	23.6	Diversified	309	26.1	32.4	11.1	2,502	23.1	12.4
21	17	**Chevron**	2,708	–5.7	7.5	Petroleum	225	94.0	8.2	8.3	2,457	7.1	9.2
22	23	**Ashland Oil[e]**	2,586	3.9	25.4	Petroleum	108	12.5	36.4	4.2	958	17.3	11.3
23	22	**Ciba**	2,519	–0.2	55.2	Specialty chemicals	na	na	na	na	na	na	na
24	20	**Praxair**	2,438	–6.4	100.0	Basic chemicals	341	23.6	100.0	14.0	3,255	100.0	10.5
25	26	**Phillips Petroleum**	2,308	3.7	18.8	Petroleum	97	148.7	9.1	4.2	2,011	18.5	4.8
26	27	**Akzo**	2,241	11.7	100.0	Basic chemicals	196	28.9	100.0	8.8	na	na	na
27	25	**Rhône-Poulenc**	2,200	–4.3	100.0	Specialty chemicals	na	na	na	na	na	na	na
28	29	**Dow Corning**	2,044	4.5	100.0	Specialty chemicals	236	11.9	100.0	11.5	3,265	100.0	7.2
29	35	**Ethyl**	1,938	14.5	100.0	Basic chemicals	168	–22.9	100.0	8.6	2,009	100.0	8.3
30	—	**Huntsman Chemical**	1,850	15.6	100.0	Basic chemicals	na	na	na	na	na	na	na
31	28	**Hercules**	1,843	–12.7	66.5	Basic chemicals	252	1.2	81.8	13.7	1,375	61.0	18.3
32	31	**FMC**	1,837	1.0	48.9	Machinery	197	–7.5	52.5	10.7	1,522	54.1	13.0
33	30	**National Starch**	1,808	–1.0	100.0	Specialty chemicals	288	3.3	100.0	15.9	1,672	100.0	17.2
34	36	**Great Lakes Chemical**	1,792	19.7	100.0	Specialty chemicals	415	15.0	100.0	23.2	1,901	100.0	21.8
35	34	**Elf Atochem**	1,700	0	100.0	Basic chemicals	na	na	na	na	na	na	na
36	38	**Lubrizol**	1,526	6.4	100.0	Specialty chemicals	190	2.6	100.0	12.5	1,055	89.2	18.0
37	24	**American Cyanamid[d]**	1,411	8.5	33.0	Specialty chemicals	na	na	na	na	na	na	na
38	40	**Nalco Chemical**	1,389	1.1	100.0	Specialty chemicals	263	1.0	100.0	18.9	1,212	100.0	21.7
39	39	**Lyondell Petrochemical**	1,326	–5.9	34.4	Petroleum products	57	–58.7	61.3	4.3	688	55.9	8.3
40	42	**Morton International[f]**	1,274	3.2	55.2	Specialty chemicals	135	–18.1	42.9	10.6	1,273	56.8	10.6
41	58	**Witco**	1,233	47.3	57.5	Specialty chemicals	108	45.7	94.5	8.8	1,037	56.4	10.4
42	45	**Solvay America**	1,200	4.4	100.0	Basic chemicals	na	na	na	na	na	na	na
43	44	**Cabot[e]**	1,192	0.9	73.8	Basic chemicals	149	–3.8	89.9	12.5	1,117	75.0	13.3
44	46	**International Flavors**	1,189	5.5	100.0	Specialty chemicals	311	16.0	100.0	26.2	1,225	100.0	25.4
45	47	**PPG Industries**	1,150	3.4	20.0	Glass products	138	–25.4	18.5	12.0	1,092	19.3	12.6
46	49	**Olin**	1,117	12.1	46.1	Basic chemicals	na	na	na	na	na	na	na
47	37	**Texaco**	1,114	–23.9	3.2	Petroleum	na	na	na	na	na	na	na
48	41	**BP America**	1,038	–19.8	6.6	Petroleum	26	–59.4	1.8	2.5	na	na	na
49	52	**Henkel**	1,010	14.6	100.0	Specialty chemicals	na	na	na	na	na	na	na
50	—	**Cytec**	1,008	–3.5	100.0	Basic chemicals	na	na	na	na	na	na	na

Rank 1993	Rank 1992		Chemical sales 1993 ($ millions)	Change from 1992	Chemical sales as % of total sales	Industry classification	Chemical operating profits[a] ($ millions)	Change from 1992	Chemical operating profits as % of total profits	Operating profit margin[b]	Identifiable chemical assets ($ millions)	Chemical assets as % of total assets	Operating return on chemical assets[c]
51	52	**H. B. Fuller[g]**	$975	4.5%	100.0%	Specialty chemicals	$54	–25.1%	100.0%	5.5%	$565	100.0%	9.5%
52	—	**Geon**	973	8.7	100.0	Basic chemicals	24	–384.7	100.0	2.5	721	100.0	3.4
53	50	**Tenneco**	914	–3.9	6.9	Diversified	83	6.4	6.7	9.1	721	4.7	11.5
54	—	**Hanson**	911	12.2	12.6	Diversified	na	na	na	na	na	na	na
55	51	**Engelhard**	910	–4.1	42.3	Diversified	137	7.2	81.5	15.0	788	61.6	17.4
56	57	**Uniroyal Chemical**	908	6.1	100.0	Specialty chemicals	110	0.1	100.0	12.1	1,225	100.0	8.9
57	54	**CF Industries**	906	0.8	100.0	Agrochemicals	–21	def	def	def	951	100.0	–6.7
58	48	**IMC Fertilizer[f]**	897	–15.2	100.0	Agrochemicals	19	–90.1	100.0	2.1	2,056	100.0	0.9
59	54	**Farmland Industries[h]**	893	–0.6	18.9	Agricultural supplies	49	–55.3	63.6	5.5	325	18.9	15.1
60	—	**Wellman**	842	1.7	100.0	Basic chemicals	76	–31.3	100.0	9.1	1,015	100.0	7.5
61	32	**BF Goodrich**	830	–53.3	45.6	Basic chemicals	53	92.0	62.6	6.4	687	29.1	7.7
62	62	**CBI Industries**	826	10.7	49.4	Construction	113	4.8	95.7	13.6	na	na	na
63	69	**Arcadian Partners**	799	34.8	100.0	Agrochemicals	69	–10.0	100.0	8.6	1,015	100.0	6.8
64	65	**Fina**	793	12.3	23.2	Petroleum	60	–39.4	117.3	7.6	402	16.0	15.0
65	59	**Aristech**	788	–1.4	100.0	Basic chemicals	na	na	na	na	na	na	na
66	61	**Georgia Gulf**	769	–1.4	100.0	Basic chemicals	111	–14.2	100.0	14.4	405	100.0	27.3
67	66	**Vista Chemicals[f]**	701	3.9	100.0	Basic chemicals	na	na	na	na	na	na	na
68	56	**NL Industries**	697	–22.0	86.6	Basic chemicals	36	–55.9	57.9	5.2	1,008	83.6	3.6
69	64	**Betz Laboratories**	685	–3.1	100.0	Specialty chemicals	101	–22.8	100.0	14.8	521	100.0	19.4
70	60	**Freeport-McMoRan**	619	–22.5	38.5	Agrochemicals	–56	def	def	def	1,194	32.2	–4.7
71	71	**Sigma-Aldrich**	613	10.8	82.9	Specialty chemicals	149	8.5	89.7	24.2	658	87.4	22.6
72	67	**Loctite**	613	0.8	100.0	Specialty chemicals	na	na	na	na	na	na	na
73	71	**Kerr-McGee**	556	8.0	16.9	Petroleum	70	–11.4	35.2	12.6	733	20.7	9.5
74	70	**Intl. Specialty Products**	548	–3.9	100.0	Specialty chemicals	65	–39.6	100.0	11.9	na	na	na
75	75	**GenCorp**	519	7.7	27.2	Rubber products	47	4.4	38.8	9.1	na	na	na
76	80	**Sterling Chemical**	519	20.5	100.0	Basic chemicals	15	–12.4	100.0	3.0	540	100.0	2.9
77	73	**Union Camp**	519	3.7	16.6	Diversified	49	56.9	23.1	9.4	385	8.2	12.7
78	68	**Merck**	510	–14.2	4.9	Drugs	na	na	na	na	na	na	na
79	73	**Hüls America**	500	0	100.0	Specialty chemicals	na	na	na	na	na	na	na
80	86	**Degussa**	481	30.8	34.0	Specialty chemicals	na	na	na	na	na	na	na
81	76	**Aluminum Co. of America**	479	0.7	5.3	Nonferrous metals	na	na	na	na	na	na	na
82	63	**Unocal**	460	–37.2	5.5	Petroleum	65	75.7	10.6	14.1	387	4.2	16.8
83	77	**Ferro**	449	–4.2	42.1	Specialty materials	24	20.2	24.9	5.3	238	37.2	10.0
84	79	**Stepan**	439	0.7	100.0	Specialty chemicals	20	–35.7	100.0	4.5	300	100.0	6.5
85	82	**Borden Chemicals**	433	7.8	100.0	Basic chemicals	17	–63.9	100.0	3.8	444	100.0	3.7
86	—	**Rexene**	429	3.5	100.0	Basic chemicals	15	34.2	100.0	3.4	430	100.0	3.4
87	85	**Lonza**	420	10.5	100.0	Specialty chemicals	na	na	na	na	na	na	na
88	83	**Crompton & Knowles**	407	3.1	73.0	Specialty chemicals	68	7.3	72.4	16.7	282	77.6	24.2
89	79	**Mallinckrodt**	395	–10.3	22.0	Specialty chemicals	na	na	na	na	na	na	na
90	81	**Sun Co.**	389	–5.7	4.2	Petroleum	na	na	na	na	na	na	na
91	84	**Vulcan Materials**	377	–3.8	33.2	Nonmetallic minerals	17	–66.1	12.9	4.6	na	na	na
92	88	**Petrolite[i]**	333	10.3	94.5	Specialty chemicals	30	21.7	94.1	8.9	259	86.0	11.5
93	92	**Mississippi Chemical**	289	20.6	74.8	Farm cooperative	23	–27.7	473.5	7.8	287	89.4	7.9
94	87	**First Mississippi[f]**	285	–9.3	66.3	Agrochemicals	38	–4.6	155.8	13.2	168	50.7	22.5
95	89	**Calgon Carbon**	269	–9.7	100.0	Basic chemicals	33	–29.2	100.0	12.3	337	100.0	9.8
96	91	**Georgia-Pacific**	267	11.3	2.2	Wood products	na	na	na	na	na	na	na
97	90	**Agricultural Minerals**	260	6.7	100.0	Agrochemicals	53	–5.3	100.0	20.4	286	100.0	18.5
98	—	**Terra Industries**	229	82.4	18.5	Agrochemicals	29	93.9	58.5	12.5	na	na	na
99	94	**Nova**	222	–1.4	100.0	Basic chemicals	na	na	na	na	na	na	na
100	96	**Cambrex Corp.**	197	9.9	100.0	Specialty chemicals	17	20.4	100.0	8.4	167	100.0	10.0

a Operating profit is sales less administrative expenses and cost of sales. **b** Chemical operating profit as a percentage of sales. **c** Chemical operating profit as a percentage of identifiable chemical assets. **d** Chemical sales include significant amounts of nonchemical products. **e** Fiscal year ended Sept. 30. **f** Fiscal year ended June 30. **g** Fiscal year ended Nov. 30. **h** Fiscal year ended Aug. 31. **i** Fiscal year ended Oct. 31. **na** = not available. **def** = deficit.

FINANCIAL ANALYSIS: Most ratios at chemical companies continued to fall

		Profit margin[a]	Return on investment[b]	Debt as % of debt plus equity	% total sales abroad[c]	% total assets abroad[d]	Sales per employee[e]	Dividends as % of net income	CAPITAL SPENDING[f]		R&D as % of sales	Sales as % of assets	Net plant as % of gross plant
									As % of sales	As % of net plant			
Air Products[g]	1993	6.0%	2.8%	32.6%	25.2%	31.0%	$236	50.7%	14.7%	18.1%	2.8%	69.9%	45.5%
	1992	8.6	4.1	31.3	27.6	33.3	222	33.7	13.3	15.6	2.6	71.6	47.5
American Cyanamid	1993	8.1	5.6	20.1	39.8	27.3	161	44.5	7.1	17.3	13.9	70.6	57.0
	1992	7.5	6.1	13.0	38.8	24.4	161	37.0	7.8	19.3	10.7	97.3	53.0
Arco Chemical	1993	6.7	5.1	36.0	34.5	36.4	na	112.1	5.7	8.3	2.3	91.1	66.7
	1992	8.5	6.1	39.0	42.9	36.6	728	94.9	9.9	13.2	2.2	83.0	70.5
Betz Laboratories	1993	10.7	9.6	24.6	20.7	23.3	166	64.6	9.2	21.0	4.2	131.4	54.2
	1992	11.6	11.5	24.8	21.2	22.2	170	54.8	10.5	25.8	4.0	138.5	56.6
Cabot[g]	1993	3.5	3.2	50.9	41.5	42.7	299	40.2	4.0	10.1	2.8	108.4	51.7
	1992	4.0	3.4	49.3	46.1	46.7	288	36.5	5.0	11.1	2.4	100.2	55.2
Calgon Carbon	1993	7.1	4.6	2.6	38.4	31.9	204	34.3	5.6	7.7	2.4	79.9	69.4
	1992	9.6	7.2	2.8	40.2	33.0	202	22.8	8.1	11.8	2.1	89.2	74.2
Crompton & Knowles	1993	9.3	13.2	5.5	18.5	22.8	240	37.5	2.6	14.3	2.0	153.7	57.7
	1992	8.4	11.7	10.2	20.1	23.3	237	34.2	2.5	13.0	2.0	147.6	60.6
Dow Chemical	1993	3.6	2.2	42.4	48.6	41.6	326	111.6	7.8	16.5	7.0	70.8	39.7
	1992	2.9	1.9	43.4	49.7	42.6	309	128.9	8.5	18.3	6.8	74.8	41.0
Eastman Chemical	1993	6.8	3.6	62.9	21.7	10.7	216	6.7	9.4	12.0	4.5	89.9	47.9
	1992	7.9	4.2	0	23.5	8.2	206	23.3	12.3	15.3	4.3	90.7	49.3
Ethyl	1993	5.8	4.3	47.7	32.5	31.3	352	63.2	10.6	20.5	3.9	96.5	52.3
	1992	9.1	11.1	24.8	17.2	5.0	472	26.4	5.3	19.0	2.5	32.3	50.6
First Mississippi[h]	1993	0.6	0.5	41.4	13.7	na	na	223.4	2.6	5.5	1.2	112.1	55.8
	1992	0.8	0.7	43.4	15.5	na	na	140.1	6.4	12.1	0.8	112.1	56.6
Freeport-McMoRan	1993	def	def	99.9	na	na	na	def	35.3	20.5	na	43.4	65.9
	1992	11.3	4.4	80.5	na	na	na	95.7	38.8	28.2	na	46.7	68.9
H. B. Fuller[i]	1993	2.8	3.8	19.5	46.3	77.9	163	27.8	4.3	18.0	2.2	172.8	55.4
	1992	3.8	5.1	17.3	47.4	71.2	161	18.0	3.7	15.4	2.2	166.4	56.5
Georgia Gulf	1993	5.5	7.5	143.4	na	na	684	0	3.8	13.2	na	189.7	57.3
	1992	5.9	8.5	164.9	na	na	691	0	1.8	6.7	na	185.8	59.9
BF Goodrich	1993	0.8	0.7	35.2	11.0	7.0	136	422.2	8.0	17.5	3.7	77.0	61.4
	1992	0.4	0.3	32.7	11.2	7.8	189	638.6	7.9	16.5	3.3	103.0	55.5
W. R. Grace	1993	3.0	2.8	43.6	35.2[j]	20.1[j]	130	95.5	7.0	21.3	3.1	72.2	52.3
	1992	4.0	4.1	46.7	37.0[j]	11.3[j]	125	57.4	7.2	23.3	2.7	98.6	51.9
Great Lakes Chemical	1993	14.9	16.2	4.6	51.7	41.7	na	9.2	4.3	16.9	3.0	96.2	56.3
	1992	15.6	15.4	4.2	49.0	45.0	na	9.5	4.6	16.1	3.1	86.4	58.2
Hercules	1993	7.5	4.6	18.8	28.1	19.9	197	45.6	5.4	11.4	2.7	87.7	40.0
	1992	5.9	3.8	19.8	29.4	19.2	186	59.9	5.2	11.1	2.5	88.8	42.1
IMC Fertilizer[h]	1993	def	def	67.5	15.9	14.3	na	def	11.8	8.0	na	43.6	54.8
	1992	8.6	3.5	50.6	14.2	16.5	na	26.2	16.8	14.0	na	57.6	54.6
International Flavors	1993	17.0	13.6	0	67.5	50.1	272	56.6	6.9	25.4	6.3	97.0	53.0
	1992	15.7	11.6	0	68.9	43.3	266	59.1	4.4	17.3	6.3	88.9	51.7

		Profit margin[a]	Return on investment[b]	Debt as % of debt plus equity	% total sales abroad[c]	% total assets abroad[d]	Sales per employee[e]	Dividends as % of net income	CAPITAL SPENDING[f] As % of sales	CAPITAL SPENDING[f] As % of net plant	R&D as % of sales	Sales as % of assets	Net plant as % of gross plant
Lawter International	1993	14.5%	10.9%	3.7%	45.6%	26.7%	$321	71.7%	7.5%	29.3%	2.6%	82.2%	50.3%
	1992	16.1	13.0	3.7	45.1	27.5	366	65.0	4.5	20.6	2.4	89.4	46.6
Loctite	1993	11.1	11.2	0.8	54.1	56.7	155	41.0	7.6	28.1	4.4	101.6	58.6
	1992	11.9	12.9	3.6	60.4	64.2	165	36.2	6.6	28.9	4.3	109.1	57.1
Lubrizol	1993	7.5	6.8	7.0	55.8	42.7	329	50.8	8.4	29.2	11.3	128.3	40.2
	1992	8.1	8.0	2.8	53.0	39.6	335	44.8	6.2	25.5	5.9	137.0	39.2
Monsanto	1993	5.8	4.2	34.5	34.7	31.1	263	59.8	5.5	15.6	7.9	91.5	38.0
	1992	4.8	3.2	32.1	36.1	32.7	230	72.0	7.5	19.5	8.4	85.4	39.5
Morton International[h]	1993	7.0	6.6	15.4	24.2	20.6	194	29.0	8.7	22.0	3.0	103.2	58.2
	1992	7.1	6.5	15.4	27.1	23.6	191	32.2	9.8	24.0	3.0	96.8	58.9
Nalco Chemical	1993	11.0	10.1	31.4	35.9	32.9	204	47.1	8.5	21.1	3.6	114.6	49.4
	1992	10.5	9.3	41.8	40.7	31.9	205	47.5	9.5	24.6	3.5	101.8	51.1
Olin	1993	1.7	1.2	60.9	7.5	7.1	195	147.5	5.4	14.9	1.7	125.5	35.3
	1992	2.3	1.7	39.2	6.5	9.0	176	105.5	7.3	18.5	1.6	117.0	37.5
Petrolite[k]	1993	5.8	4.9	19.7	34.2	24.5	176	61.5	5.4	15.2	3.9	116.8	43.0
	1992	5.2	4.3	0	32.8	29.3	159	77.2	5.8	17.1	3.8	131.9	40.4
PPG Industries	1993	7.1	5.1	23.1	31.8	30.5	183	54.0	4.5	9.2	3.5	101.8	46.1
	1992	5.7	4.1	23.7	35.8	32.4	180	60.5	4.9	9.5	3.5	102.7	48.3
Praxair	1993	5.9	2.6	60.3	51.3	56.0	145	22.4	9.8	10.6	2.4	74.9	48.0
	1992	3.2	1.6	55.2	57.3	56.3	140	19.0	12.8	14.4	2.4	77.9	50.4
Quaker Chemical	1993	3.1	3.2	15.0	43.6	36.5	194	90.6	4.6	15.8	5.7	114.0	52.8
	1992	5.7	6.6	15.5	44.1	36.8	219	42.1	3.4	13.8	5.2	127.5	53.4
Rohm and Haas	1993	5.5	3.7	32.4	41.8	35.4	252	53.6	11.7	20.4	6.3	92.8	50.6
	1992	6.9	4.5	32.9	43.4	32.6	221	41.7	9.2	16.0	6.5	88.9	51.0
Sigma-Aldrich	1993	14.5	12.2	2.8	28.3	29.9	145	13.9	10.2	29.2	na	98.1	60.5
	1992	14.6	12.8	3.5	30.1	28.5	152	13.6	4.7	16.4	na	106.3	57.2
Stepan	1993	2.5	2.2	46.2	16.0	14.7	337	47.4	5.8	15.1	4.0	146.0	44.7
	1992	2.4	2.2	47.6	16.1	13.9	331	40.0	7.9	20.5	2.6	146.7	47.4
Sterling Chemicals[g]	1993	def	def	78.5	23.0	39.1	421	def	2.3	3.9	na	96.1	70.3
	1992	1.1	0.7	77.0	3.1	39.4	351	297.3	3.7	4.6	na	71.7	77.2
Union Carbide	1993	3.6	2.3	39.5	25.8	18.5	356	75.2	8.5	12.3	3.0	99.0	57.0
	1992	2.4	1.6	47.3	27.6	21.2	323	109.2	7.4	11.3	3.2	98.6	56.7
Witco	1993	3.7	3.8	41.0	29.1	35.9	261	55.9	4.8	14.9	2.3	116.5	52.8
	1992	3.9	3.3	22.0	22.2	37.7	199	60.2	4.2	10.1	1.7	95.4	56.0
AVERAGE 1993		5.3%	3.6%	38.6%	35.9%	31.7%	$226	64.7%	7.9%	15.3%	5.2%	84.7%	48.1%
AVERAGE 1992		5.6%	4.0%	33.5%	36.7%	29.6%	$221	58.5%	8.4%	16.7%	4.9%	83.4%	49.1%

Note: Net income is from continuing operations, excluding significant nonrecurring and extraordinary items. **a** Net income as a percentage of sales. **b** Net income as a percentage of current assets plus gross plant. **c** Consolidated sales only. **d** Foreign identifiable assets as a percentage of total assets. **e** Thousands of dollars. **f** Actual spending on new facilities and purchase of land and new equipment in consolidated companies. **g** Fiscal year ended Sept. 30. **h** Fiscal year ended June 30. **i** Fiscal year ended Nov. 30. **j** Excludes Canada. **k** Fiscal year ended Oct. 31. **na** = not available. **def** = deficit.

Chemical capital spending continued to fall in 1993

Capital spending declined for the third year in a row at major chemical companies in 1993. Big-budget projects continued to feel the lingering effects of the 1991–92 recession as capital spending at 24 major chemical makers surveyed by C&EN dropped an average of 10% last year to a collective $6.9 billion. Capital spending as a percentage of sales also declined in 1993 to 8.0%. The last time spending as a percentage of sales was so low was in 1987.

The drop in capital spending follows an average 9% decline in 1992 and a 13% cutback in 1991. Still, none of these drops are as large as the 25% downturn a decade ago in 1983 when industry overcapacity and recession forced capital outlays to hit their 10-year low of $4.7 billion.

The chemical industry had more than adequate capacity in place as the U.S. came out of recession in late 1992 and early 1993. Because of hefty investments between 1988 and 1990, coupled with falling earnings for the past four years for the industry as a whole, most major chemical companies opted to cut back further on building new plants in 1993.

Between 1988 and 1990, the major chemical companies invested heavily in their operations. As both profits and demand for products rose during those years, capital spending was increased at double-digit rates. Capital expenditures for the group reached a 10-year peak of $9.7 billion in 1990.

The Department of Commerce's survey of the chemical industry, based on a much larger number of companies than those surveyed by C&EN, shows capital spending also declined in 1993. That survey registered a 6% spending decline last year to $21.8 billion.

The reason for the discrepancy in the two surveys is that the 24 major chemical companies C&EN monitors are all identified by the Commerce Department as producers of industrial chemicals and synthetic materials. Such producers make up less than half of the companies in the Department of Commerce's survey of the chemical industry, which also includes manufacturers of pharmaceuticals, soaps, toiletries, and paints. For 1994, the government survey projects an 8% increase in capital outlays for the broadly defined chemical industry.

All manufacturing companies increased capital spending 3% in 1993 to $179 billion, the Commerce Department finds. That follows two years of declining overall investment in new plants and equipment. Generally, the turnaround for manufacturing companies coupled with solid evidence of growth in many key markets for chemicals—such as housing and motor vehicles—suggests that the chemical industry, too, may soon increase its capital outlays.

A separate Commerce Department survey of capital spending abroad shows that U.S. chemical companies have slowed their capital outlays outside the U.S. as well. Spending declined 2% to $6.2 billion in 1993, following bigger drops of 3% in 1992 and 6% in 1991. The Commerce Department predicts a recovery in 1994, with chemical firms planning to spend $6.6 billion abroad, more than 6% above the 1993 level. The survey also indicates that all U.S. manufacturing firms dropped their overseas capital investment 3% in 1993 to $27.7 billion—a figure that is likely to increase a substantial 9% in 1994.

INDUSTRY CAPITAL SPENDING: Resumed growth for all manufacturing last year

$ Billions	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994[a]
All manufacturing	$138.82	$153.48	$142.69	$145.90	$165.70	$183.80	$192.61	$182.81	$174.02	$179.18	$191.60
Chemicals & allied products	15.32	16.44	16.81	16.42	19.25	18.47	20.63	21.52	23.15	21.78	23.50
Iron & steel	3.54	4.12	3.32	4.69	6.16	7.87	7.78	6.53	5.64	5.60	7.71
Nonferrous metals	2.13	1.88	1.93	2.16	2.77	2.64	2.88	2.81	2.67	2.57	2.24
Paper	7.21	8.59	8.77	9.01	11.23	15.58	16.53	11.50	10.53	10.30	10.79
Petroleum	25.53	26.71	17.92	17.12	19.93	30.08	34.79	35.59	29.59	28.54	27.95
Rubber	3.11	3.86	3.89	3.52	3.86	3.79	3.48	3.43	3.85	3.30	3.61
Stone, clay, glass	3.09	3.40	3.14	3.37	3.59	4.00	3.29	2.89	3.36	4.30	4.81

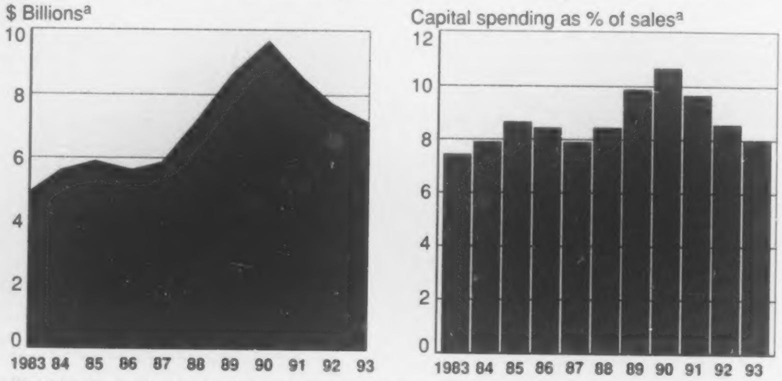
a Estimated. **Source:** Department of Commerce

U.S. chemical makers decreased capital spending abroad in 1993, but plan increases in 1994

$ Billions[a]	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994[b]
All manufacturing	$13.6	$14.9	$16.4	$17.2	$22.4	$28.6	$31.1	$28.5	$28.6	$27.7	$30.1
Chemicals & allied products	2.4	2.7	3.1	3.7	4.9	6.4	6.9	6.5	6.3	6.2	6.6
Metals, primary & fabricated	1.0	0.9	0.9	0.8	1.2	1.8	1.9	1.1	1.1	1.2	1.2
Petroleum	14.1	13.7	9.6	9.8	13.3	14.5	15.9	18.6	18.4	19.2	20.8

a By majority-owned affiliates of U.S. companies. b Planned. **Source:** Department of Commerce

Chemical capital spending down for third year in a row



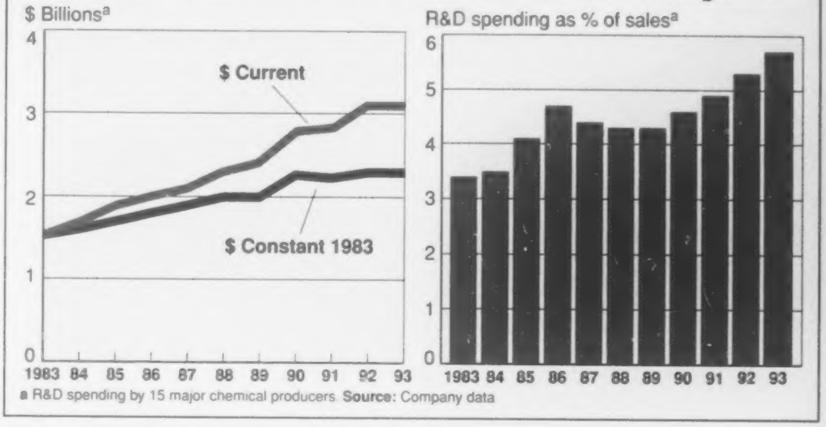
a Worldwide data for 24 major chemical producers. **Source:** Company data

CHEMICAL CAPITAL SPENDING: At lowest level in six years for major chemical companies

$ Millions	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
Air Products	$246	$263	$392	$367	$323	$387	$414	$468	$506	$428	$491
Cabot[a]	80	505	184	80	83	170	192	174	198	78	65
Crompton & Knowles	2	3	3	4	4	7	13	16	11	13	14
Dow Chemical	630	781	806	890	995	1,267	1,764	2,119	1,908	1,608	1,414
DuPont[b]	888	989	1,176	1,229	1,357	1,735	2,106	2,608	2,045	2,058	1,667
Ethyl	85	103	90	134	139	151	119	152	166	157	205
H. B. Fuller	15	13	15	13	30	40	41	31	30	34	42
BF Goodrich	115	153	202	144	143	181	240	243	219	200	146
W. R. Grace	353	380	348	199	243	418	485	514	447	398	310
Great Lakes Chemical	20	29	21	18	35	47	40	49	71	69	69
Hercules	168	218	234	257	205	251	293	273	214	150	149
Loctite	9	10	9	11	17	15	24	29	34	40	46
Lubrizol	25	30	40	41	42	55	65	77	82	96	128
Monsanto	560	614	645	520	505	590	607	750	591	586	437
Nalco Chemical	41	53	60	64	57	62	86	115	137	131	118
Olin	123	165	154	128	115	147	142	187	177	173	132
PPG Industries	450	315	452	498	499	410	671	567	335	282	258
Petrolite	9	11	24	25	19	20	19	18	22	18	19
Praxair[c]	—	—	—	—	—	—	—	—	—	333	240
Quaker Chemical	2	4	6	5	4	5	8	13	8	7	9
Rohm and Haas	72	124	159	179	222	338	385	412	265	283	382
Stepan	10	12	19	14	26	20	34	38	34	34	25
Union Carbide	761	670	649	524	502	671	785	744	817	359	395
Witco	55	85	76	60	69	72	70	91	74	73	104
TOTAL	**$4,719**	**$5,530**	**$5,764**	**$5,404**	**$5,634**	**$7,059**	**$8,603**	**$9,688**	**$8,391**	**$7,608**	**$6,865**
ANNUAL CHANGE	**–25%**	**17%**	**4%**	**–6%**	**4%**	**25%**	**22%**	**15%**	**–13%**	**–9%**	**–10%**

Note: Figures are for worldwide spending on construction, equipment, and land in consolidated businesses. Where possible, acquisition costs and investments in nonconsolidated businesses are excluded. Prior years are not restated to reflect company revisions. a Includes acquisitions and investments. b Excludes Conoco. c Spun off from Union Carbide in 1992.
Source: Company data

R&D share of sales continues to rise at chemical companies



a R&D spending by 15 major chemical producers. **Source:** Company data

R&D SPENDING: Chemical firms hold on to 1992 gains as other companies cut back

$ Millions	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
CHEMICAL COMPANIES											
Air Products[a]	$40	$44	$51	$61	$57	$72	$71	$72	$80	$85	$92
Dow Chemical	492	507	547	605	670	772	873	1,136	1,159	1,289	1,256
Ethyl[b]	39	40	47	47	50	59	61	65	69	73	76
W. R. Grace	73	81	92	94	107	119	125	148	150	151	135
Hercules	74	72	76	71	74	74	79	92	86	70	76
International Flavors	32	32	34	39	45	50	52	57	62	71	75
Lubrizol	37	33	44	51	62	65	70	74	80	90	172
Monsanto	290	370	470	596	615	648	598	612	627	651	626
Morton International[c,d,e]	23	30	25	29	31	35	38	48	59	61	69
Nalco Chemical	30	32	32	33	35	37	41	45	47	48	50
Olin	49	52	53	56	62	58	66	66	41	39	41
Petrolite	13	12	12	12	12	12	12	12	11	12	14
Praxair[f]	—	—	—	—	—	—	—	—	—	62	58
Rohm and Haas	100	109	124	133	142	156	175	178	183	199	205
Union Carbide	245	265	275	148	159	159	181	191	190	155	139
TOTAL	**$1,537**	**$1,679**	**$1,882**	**$1,975**	**$2,121**	**$2,316**	**$2,442**	**$2,796**	**$2,844**	**$3,056**	**$3,084**
ANNUAL CHANGE	**7%**	**9%**	**12%**	**5%**	**7%**	**9%**	**5%**	**14%**	**2%**	**7%**	**1%**
PHARMACEUTICAL & DIVERSIFIED COMPANIES											
AlliedSignal[c]	$280	$295	$343	$459	$400	$415	$381	$426	$381	$320	$313
American Cyanamid	208	232	251	278	314	365	406	460	492	566	596
AT&T Bell Labs	2,000	1,900	1,900	2,100	2,250	2,660	2,800	2,900	3,100	3,200	3,069
Bristol-Myers Squibb	301	344	412	474	563	688	789	881	993	1,083	1,128
DuPont	966	1,097	1,144	1,156	1,223	1,319	1,387	1,428	1,298	1,277	1,132
Eli Lilly	294	341	370	427	466	512	605	703	767	925	955
FMC	102	121	149	146	132	144	150	158	135	145	149
IBM	2,500	3,148	3,457	3,975	3,998	4,419	5,201	4,419	5,001	5,003	4,431
Merck & Co.	356	393	426	480	566	669	751	854	998	1,112	1,173
3M	396	454	520	586	650	721	784	865	914	1,007	1,030
Pfizer	230	255	287	336	401	473	531	640	757	863	974
PPG Industries	127	150	176	204	227	232	233	218	220	203	201
Procter & Gamble[d]	327	369	400	479	549	615	628	693	786	861	956
Schering-Plough	145	164	175	212	251	298	327	380	426	522	578
Upjohn	218	247	284	314	356	380	407	427	491	549	642
TOTAL	$8,450	$9,510	$10,294	$11,626	$12,346	$13,910	$15,380	$15,452	$16,759	$17,636	$17,327
ANNUAL CHANGE	12%	13%	8%	13%	6%	13%	11%	1%	9%	5%	–2%

Note: Prior years are not restated to reflect company revisions. **a** For fiscal year ending Sept. 30. **b** Beginning in 1989, excludes Tredegar Industries, spun off in 1989. **c** Includes all company-financed R&D but excludes contract R&D. **d** Fiscal year ends June 30. **e** Data for Morton Thiokol prior to 1985. **f** Spun off from Union Carbide in 1992. **Source:** Company data

SHIPMENTS: Except for drugs, chemical categories grew less than all manufacturing

$ Billions	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	% annual change 1992–93	% annual change 1983–93
All manufacturing industries	$2,070.7	$2,288.2	$2,334.5	$2,335.9	$2,475.9	$2,682.5	$2,792.7	$2,873.6	$2,821.9	$2,934.1	$3,100.7	6%	4%
Chemicals & allied products	189.6	206.0	204.8	205.7	229.5	259.7	278.1	288.2	289.0	301.5	312.5	4	5
Industrial chemicals	109.1	119.4	114.7	112.2	126.2	145.5	156.2	157.3	152.3	156.4	160.9[a]	3	4
Drugs, soaps & toiletries	54.6	57.7	61.3	66.4	74.0	81.8	88.0	95.2	101.9	110.4	118.0[a]	7	8
Petroleum & coal products	187.8	184.5	176.6	122.6	130.4	131.4	143.7	172.7	160.4	154.6	147.0	–5	–2
Rubber & plastic products	62.9	72.9	75.6	78.4	86.6	94.2	98.4	101.4	103.6	103.3	104.5	1	5
Paper & allied products	84.8	95.5	94.7	99.9	109.0	122.6	131.4	131.4	124.4	131.3	129.2	–2	4

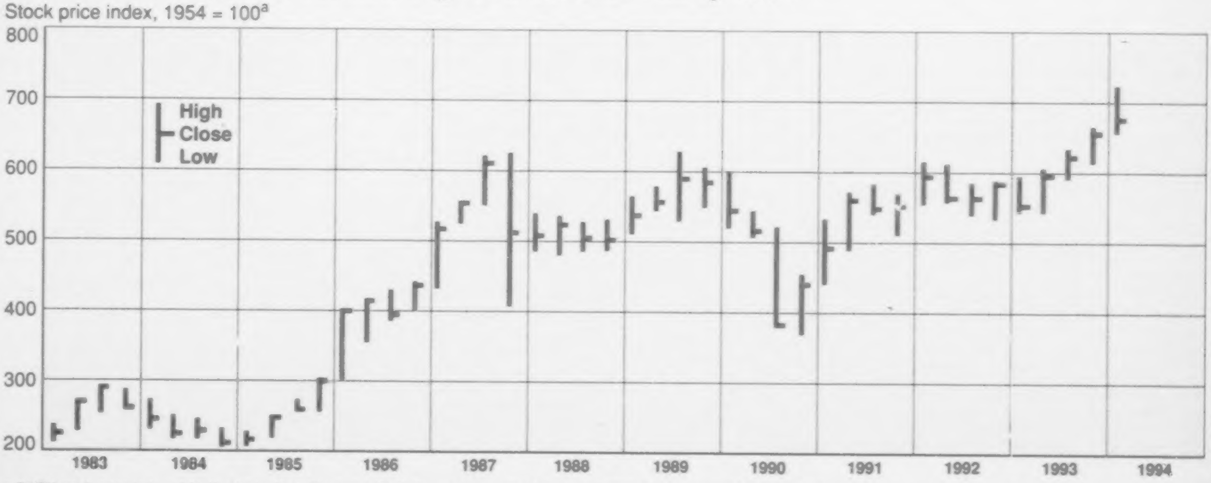
[a] Preliminary. **Source:** Department of Commerce

PRICES: Little change for either chemicals or all commodities

Producer price indexes, 1982 = 100	Annual average 1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	% annual change 1992–93	% annual change 1983–93
All commodities	101.3	103.7	103.1	100.2	102.8	106.9	112.2	116.3	116.5	117.2	118.9	1%	2%
Industrial commodities	101.1	103.3	103.7	99.9	102.6	106.3	111.6	115.8	116.5	117.4	119.0	1	6
Finished goods	101.6	103.7	104.7	103.2	105.4	108.0	113.6	119.2	121.7	123.2	124.7	1	2
Chemicals & allied products	100.2	102.9	103.7	102.5	106.4	116.3	123.0	123.6	125.6	125.9	128.2	2	3
Industrial chemicals	97.3	96.8	96.0	91.5	95.5	106.8	114.8	113.2	111.8	109.3	110.4	1	1
Prepared paint	100.7	103.7	105.3	107.0	108.1	112.2	119.5	124.8	129.9	131.6	133.2	1	3
Paint materials	100.3	108.2	109.5	104.4	107.3	115.7	129.1	136.3	135.8	131.1	131.5	0	3
Drugs & pharmaceuticals	107.7	114.2	122.2	129.9	139.1	148.4	160.0	170.8	182.6	192.2	200.9	5	6
Fats & oils, inedible	106.2	139.1	110.6	80.5	92.7	10.9	95.5	88.1	86.8	93.0	95.6	3	–1
Agricultural chemicals & chemical products	96.0	97.4	96.2	94.2	96.4	104.5	108.7	107.4	111.7	110.3	109.9	0	1
Plastic resins & materials	102.4	108.9	107.5	104.4	110.3	132.4	133.4	124.1	120.0	116.4	117.1	–1	1
Other chemicals & allied products	101.3	102.7	105.2	105.8	107.0	111.9	117.3	118.9	121.5	123.3	125.5	2	1
Rubber & plastic products	100.8	102.2	101.9	101.9	103.0	109.3	112.6	113.6	115.1	115.1	116.0	1	1

Source: Department of Labor

Chemical stock prices set new highs in 1993 and early 1994



[a] C&EN stock price index of Air Products, Dow Chemical, W. R. Grace, Hercules, Monsanto, Rohm and Haas, and Union Carbide, weighted according to number of shares outstanding for each company.

Major biotechnology firms post good year

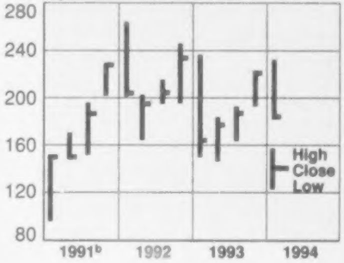
Biotechnology companies that have major biopharmaceutical products on the market had substantially increased sales in 1993. Combined sales of six industry leaders rose 26% to $2.4 billion. However, 54% of the total sales for the six companies combined were from two major products sold by Amgen.

Four of the six companies reported profits in 1993. A fifth company, Genzyme, posted a relatively small $6 million loss, the net result of R&D acquisition and restructuring costs. Similarly, Immunex's $430 million net loss resulted largely from a $346 million charge for acquiring R&D at the time of its merger with Lederle Laboratories' oncology business.

Biotechnology is such a young industry, however, that many key companies have yet to bring a major product to market or show a profit. C&EN's biotechnology stock index, which includes six firms that do not have major products and five that do, offers some measure of how investors feel about the industry as a whole. This index fluctuated from a high of 264 to a low of 163 in 1992. It remained volatile in 1993 as well. Uncertainties brought about by the specter of health care reform and setbacks for a few major products being developed scared investors away from biotechnology stocks. After dropping 89 points from the start of 1993 to reach a two-year low early in the second quarter, the index recovered most of its losses, ending 1993 just 14 points below where it ended 1992, only to fall again in early 1994.

Biotechnology stock prices remain volatile

Stock price index, close 1990 = 100[a]



a C&EN biopharmaceutical stock price index of Amgen, Applied Bioscience, Biogen, Centocor, Chiron, Cytogen, Genentech, Genetics Institute, Immunex, Repligen, and Xoma. b Based on Friday close each week, all other years based on daily close.

COMPANY RESULTS: Sales up strongly for major biotechnology companies

(Money figures in millions of dollars unless otherwise indicated)

	Net sales	Net income	R&D spending	R&D as % of sales	Total assets	Net plant and equipment	Stockholders' equity	NET INCOME			Stock price range, $ per share	Price-earnings ratio
								% of sales	% of stockholders' equity	$ per share		
Amgen												
1993	$1,306.3	$374.6[a]	$255.3	19.5%	$1,765.5	$586.9	$1,172.0	28.7%	32.0%	$2.67	$70¾–31½	19.1
1992	1,050.7	357.6[b]	182.3	17.4	1,374.3	426.0	933.7	34.0	38.3	2.43	77¾–50	26.3
1991	645.3	97.9[c]	120.9	18.7	865.5	245.7	531.1	15.2	18.4	0.67	75¾–18⅞	70.6
1990[d]	281.4	3.9[e]	72.4	25.7	459.5	150.0	309.1	1.4	1.3	0.30	21 3/16–7½	478.1
Biogen												
1993	$136.4[f]	$32.4	$79.3	58.1%	$357.0	$38.5	$325.2	23.8%	10.0%	$0.93	$47¾–24¼	38.7
1992	121.7[f]	38.3	60.4	49.6	311.2	32.3	284.9	31.5	13.4	1.12	49¾–18¼	30.4
1991	56.5[f]	7.2	44.3	78.4	253.1	28.7	239.0	12.7	3.0	0.15	49–24¼	244.2
1990	44.9[f]	7.7	36.2	80.6	158.5	23.6	145.7	17.1	5.3	0.07	29⅜–14⅜	312.5
Chiron												
1993	$147.9	$18.4	$140.0	94.7%	$968.6	$204.0	$522.3	12.4%	3.5%	$0.55	$85½–41⅛	115.1
1992[g]	111.6	(95.9)[h,i]	142.9	128.0	712.4	89.6	492.9	—	—	(3.18)[h,i]	73¾–34¾	—
1991	28.2	(425.2)[h,j]	79.4	281.6	895.3	78.0	524.4	—	—	(22.12)[h,j]	77½–37¼	—
1990	14.7	4.0[k]	50.2	341.5	265.4	24.5	120.3	27.2	3.3	0.24[k]	44¾–23½	142.2
Genentech												
1993	$457.4	$58.9	$299.4	65.5%	$1,468.8	$456.7	$1,116.8	12.9%	5.3%	$0.50	$50½–31¼	81.8
1992	391.0	20.8	278.6	71.3	1,305.1	432.5	1,007.3	5.3	2.1	0.18	39½–25⅞	181.6
1991	383.3	44.3	221.3	57.7	1,231.0	342.5	949.7	11.6	4.7	0.39	36¼–20¾	73.1
1990	367.2	(98.0)[h,l]	173.1	47.1	1,157.7	300.2	893.2	—	—	(1.05)[h]	30⅞–20⅛	—
Genzyme												
1993	$233.9	$(6.1)[h,m]	$48.3	20.6%	$542.1	$196.2	$334.1	—	—	$(0.25)[h]	$46¼–25¼	—
1992	180.0	39.5[n]	39.7	22.1	480.7	87.9	322.9	21.9%	12.2%	1.83[n]	66½–32½	27.0
1991	81.1	11.2[o]	27.2	29.1	390.5	32.1	259.9	13.8	4.3	0.50[o]	58¾–23⅜	82.1
1990	34.6	(27.2)[h,p]	18.6	53.8	118.1	29.5	96.2	—	—	(1.70)[h]	28⅝–12½	—
Immunex												
1993	$119.1[q]	$(430.3)[h,q,r]	$72.5[q]	60.0%[q]	$204.1[s]	$100.5[s]	$137.9[s]	—	—	$(9.58)[h,r,s]	$34¾–13¾[s]	—
1992	51.9	(77.6)[h,t]	37.1	71.5	235.8	97.0	134.0	—	—	(5.21)[h]	68–22½	—
1991	34.2	0.8	29.4	86.0	254.0	73.1	212.2	2.3%	0.4%	0.05	61½–33¼	947.5
1990	4.9	(9.9)[h]	23.2	473.5	121.1	36.3	106.5	—	—	(1.10)[h]	40¼–15½	—

a Includes $13.9 million legal award. **b** Includes $77 million pretax legal award. **c** Includes $129 million pretax legal assessment. **d** Figures reflect change in fiscal-year end from March 31 to Dec. 31 that occurred in 1991. **e** Includes $54.7 million royalty buyout. **f** Includes royalty income from licensees' sales of several major products. **g** Includes results of Cetus following Dec. 12, 1991, acquisition, and of Intraoptics following Jan. 8, 1992, acquisition. **h** Net loss. **i** Includes $40 million write-off of technologies but excludes $6.7 million loss from retirement of debt ($0.22 per share). **j** Includes $426 million charge for acquiring Cetus but excludes $100,000 gain for operating loss carryforward ($0.01 per share). **k** Excludes $2.8 million gain for operating loss carryforward ($0.16 per share). **l** Includes $167.7 million charge related to merger with Hoffmann-La Roche. **m** Includes $49 million purchase of R&D and $26.5 million goodwill and restructuring costs. **n** Excludes $51 million purchase of R&D, $17 million purchase of option rights, and $1.8 million charge for Vivigen acquisition ($3.24 per share). **o** Excludes $8.4 million gain for operating loss carryforward ($0.37 per share). **p** Includes $20.8 million purchase of R&D and $9.1 million repurchase option. **q** Merged June 2, 1993, with Lederle Laboratories oncology business; combined figures for predecessor and successor company. **r** Includes $346.4 million for acquisition of in-process R&D, $14.8 million for merger costs, and $25.6 million for modified stock option plan. **s** Merged June 2, 1993, with Lederle Laboratories oncology business; figures for successor company only. **t** Includes $58.7 million purchase of R&D.

Explanation of column headings in tables of company results

Year. Data are for calendar year unless otherwise indicated. Data for earlier years are not restated to reflect subsequent acquisitions or divestitures.

Net sales. Gross sales, less discounts, allowances, and returns; generally excludes excise taxes and other operating income or revenues.

Net income. Net sales and other income, less operating costs, nonoperating charges, depreciation, depletion, interest expense, deferred charges, minority interest in income, and taxes. Nonrecurring or extraordinary credits and charges have been excluded in most cases, and are indicated by a footnote.

Total assets. Sum at year's end of current assets, investments, prepaid expenses, net plant and equipment, and other tangible assets. Excludes insofar as possible intangible assets including goodwill, value of patents, and the like.

Net plant and equipment. Value at year's end of fixed assets, less accumulated depreciation, amortization, and depletion.

Capital expenditures. Total spending during the year for new fixed assets, such as plant, equipment, and land, and for replacement and modernization of facilities.

Stockholders' equity. Equity at year's end of preferred and common stockholders, including value of capital stock, capital and earned surplus, and surplus reserves, as well as contingency and miscellaneous reserves for which no definite purpose is stated. Intangible assets are deducted insofar as possible.

Net income (breakdown). Percent of sales: net income divided by net sales. Percent of stockholders' equity: net income divided by stockholders' equity. Dollars per share: net income, less preferred dividends, divided by the number of shares of common stock outstanding. All figures are adjusted for stock splits, but no adjustment has been made for earlier years as a result of stock dividends or for dilution that might result from the conversion of preferred stock or debt to common stock or the exercise of stock options outstanding.

Dividends per share. Cash dividends paid (or declared) on each share of common stock; excludes the value of stock dividends, which are indicated by a footnote.

Dividend yield. Dividends per share divided by the average of the high and low prices of the common stock during the year.

Stock price range. High-low market prices of common stock during the year, adjusted for stock splits but not for stock dividends.

Price-earnings ratio. Average of the high and low prices of the common stock during the year divided by net income per share.

COMPANY RESULTS: About half of chemical firms increased sales in 1993

							NET INCOME						
Year	Net sales	Net income	Total assets	Net plant and equipment	Capital expenditures	Stockholders' equity	% of sales	% of stockholders' equity	$ per share	Dividend, $ per share	Dividend yield, % of price	Stock price range, $ per share	Price-earnings ratio
					(Money figures in millions of dollars unless otherwise indicated)								
CHEMICALS													
Air Products													
1993[a]	$3,328	$200.9[b]	$4,697	$2,705.6	$490.6	$2,037	6.0%	9.9%	$1.76[b]	$0.89	2.1%	$49⅛–37½	24.6
1992[a]	3,217	271.0	4,420	2,745.7	427.5	2,026	8.4	13.4	2.40	0.805	1.7	49½–31¾	19.4
1991[a]	2,931	248.9	4,163	2,622.6	506.4	1,777	8.5	14.0	2.22	0.75	2.6	37–21½	13.2
1990[a]	2,895	229.9	3,845	2,485.1	467.5	1,634	7.9	14.1	2.07	0.69	2.7	30½–21½	12.5
Arco Chemical													
1993	$3,192	$214.0	$3,502	$2,173.0	$181.0	$1,576	6.7%	13.6%	$2.23	$2.50	5.8%	$47¼–39¼	19.4
1992	3,098	197.0[c]	3,599	2,230.0	295.0	1,630	6.4	12.1	2.05[c]	2.50	6.0	47¼–36½	20.4
1991	2,837	188.0	3,676	2,166.0	435.0	1,696	6.6	11.1	1.96	2.50	6.4	44¼–33⅛	19.7
1990	2,830	308.0[d]	3,739	1,768.0	539.0	1,758	10.9	17.5	3.21[d]	2.50	6.8	44¼–29¾	11.5
Betz Laboratories													
1993	$685	$63.4[e]	$517	$300.7	$63.2	$295	9.3%	21.5%	$2.05[e]	$1.39	2.7%	$62⅞–40	24.3
1992	707	82.0	506	288.4	74.3	293	11.6	28.0	2.71	1.33	2.3	66¼–48¼	21.1
1991	666	75.5	471	254.6	58.4	254	11.3	29.8	2.47	1.20	2.4	62–38¾	20.4
1990	597	65.5	421	233.5	57.5	214	11.0	30.6	2.12	1.01	2.7	43¼–30¾	17.5
Borden Chemicals & Plastics													
1993	$433	($1.4)[f]	$444	$306.0	$15.0	$230	—	—	($0.04)[f]	$0.78[g]	6.1%	$17⅛–8¼[g]	—
1992	402	27.1	467	335.1	10.5	261	6.7%	10.4%	0.73[g]	1.59[g]	9.0	22⅞–12⅜[g]	24.1
1991	410	51.6	507	369.2	18.0	293	15.7	17.6	1.39[g]	1.98[g]	17.1	14¾–8⅜[g]	8.3
1990	421	45.3	544	395.8	22.1	315	10.8	14.4	1.22[g]	1.95[g]	19.0	12¾–7¾[g]	8.4
Cabot													
1993[a]	$1,614	$37.4[h]	$1,411	$646.5	$65.0	$363	2.3%	10.3%	$1.80[h]	$1.04	2.2%	$56¼–37¼	26.0
1992[a]	1,557	62.2	1,467	703.2	78.1	406	4.0	15.3	3.18	1.04	2.6	52¼–28⅛	12.6
1991[a]	1,482	39.8[i]	1,365	670.4	198.0	329	2.7	12.1	1.69[i]	1.04	3.5	35⅞–23	17.4
1990[a]	1,673	71.0	1,627	878.7	174.4	466	4.2	15.2	2.73	1.04	3.3	37½–25	11.4

[a] Fiscal year ends Sept. 30. [b] Includes charge for cost of work force reduction of $76.0 million ($0.67 per share). [c] Excludes net loss from cumulative effect of changes in accounting for health benefits for retirees and for income taxes of $2.0 million ($0.02 per share). [d] Excludes net gain from cumulative effect of change in accounting for income taxes of $43.0 million ($0.45 per share). [e] Excludes net gain from cumulative effects of changes in accounting for health benefits for retirees, pensions, and income taxes of $2.1 million ($0.07 per share). [f] Net loss. [g] Per partnership preference unit. [h] Excludes net loss from cumulative effect of changes in accounting for health benefits of retirees and for income taxes of $26.1 million ($1.39 per share). [i] From continuing operations; excludes net income from discontinued operations of $9.5 million ($0.45 per share) and net gain on disposition of discontinued operations of $77.9 million ($3.66 per share).

Year	Net sales	Net income	Total assets	Net plant and equipment	Capital expenditures	Stockholders' equity	NET INCOME			Dividends, $ per share	Dividend yield, % of price	Stock price range, $ per share	Price-earnings ratio
							% of sales	% of stockholders' equity	$ per share				
(Money figures in millions of dollars unless otherwise indicated)													
Crompton & Knowles													
1993[a]	$558	$52.0	$330	$99.9	$14.3	$207	9.3%	25.1%	$1.00	$0.38	1.7%	$27¼–17⅝	22.4
1992	518	43.3[a]	316	98.8	12.8	177	8.4	24.5	0.87[a]	0.31	1.6	23⅞–16	22.9
1991	450	35.9	276	80.2	11.4	108	8.0	33.2	0.73	0.25	1.6	20¼–8⅜	21.8
1990	390	30.0	252	76.7	16.4	87	7.7	34.5	0.61	0.195	2.1	11½–6⅝	15.0
Dexter													
1993	$887	$34.1[b]	$748	$310.0	$47.0	$244	3.8%	14.0%	$1.40[b]	$0.88	3.6%	$28⅞–20⅜	17.6
1992	951	38.2	726	298.9	52.0	260	4.0	14.7	1.58	0.88	3.6	28⅛–20⅞	15.5
1991	938	(7.1)[c]	721	299.3	61.5	250	—	—	(0.29)[c]	0.88	3.9	26⅛–18½	—
1990	908	42.1	697	274.1	43.9	278	4.6	15.1	1.74	0.88	4.1	24½–18	12.2
Dow Chemical													
1993	$18,060	$644.0	$21,071	$8,580.0	$1,397.0	$3,600	3.6%	17.9%	$2.33	$2.60	4.7%	$62–49	23.8
1992	18,971	276.0[d]	20,978	8,801.0	1,595.0	3,682	1.5	7.5	0.99[d]	2.60	4.6	62⅞–51¼	57.6
1991	18,807	942.0	20,418	8,775.0	1,908.0	5,132	5.0	18.4	3.46	2.60	5.1	58–44⅛	14.8
1990	19,773	1,384.0	19,764	8,249.0	2,119.0	4,539	7.0	30.5	5.10	2.60	4.6	75¾–37	11.1
DuPont													
1993	$37,098	$555.0	$36,775	$21,423.0	$3,621.0	$10,952	1.5%	5.1%	$0.81	$1.76	3.6%	$53⅞–44½	60.7
1992	37,799	975.0[e]	38,409	21,882.0	4,448.0	11,304	2.6	8.6	1.43[e]	1.74	3.5	54⅞–43½	34.4
1991	38,695	1,403.0	35,596	20,610.0	5,065.0	16,218	3.6	8.7	2.08	1.68	4.1	50–32¾	19.9
1990	40,047	2,310.0	37,332	21,102.0	5,383.0	15,622	5.8	14.8	3.40	1.62	4.3	42⅜–31⅜	10.8
Ethyl													
1993[f]	$1,938	$90.0[g]	$2,009	$998.3	$205.0	$640	4.6%	14.1%	$0.76[g]	$0.60	2.5%	$30⅞–16¾	31.3
1992	2,975	269.4[h]	9,070	829.8	157.4	1,267	9.1	21.3	2.27[h]	0.60	2.2	30½–23¾	11.9
1991	2,575	206.7	7,785	766.7	166.1	1,100	8.0	18.8	1.75	0.60	2.2	33–22¼	15.8
1990	2,514	232.2	6,589	677.0	151.8	947	9.2	24.5	1.95	0.60	2.2	33–20½	13.7
Ferro													
1993	$1,066	$57.5[i]	$714	$257.8	$43.7	$305	5.4%	18.9%	$1.83[i]	$0.51	1.7%	$34¾–26⅛	16.6
1992	1,098	58.8	674	227.6	44.8	323	5.4	18.2	1.90	0.45	1.6	31½–23½	14.5
1991	1,057	36.5[j]	668	234.7	39.0	301	3.5	12.1	1.16[j]	0.43	2.4	25⅝–10⅛	15.4
1990	1,125	19.4	672	255.9	59.7	292	1.7	6.6	0.55	0.43	2.7	19½–11½	28.1
First Mississippi													
1993[k,l]	$430	$2.7[m]	$384	$206.1	$39.1	$161	0.6%	1.7%	$0.13[m]	$0.30	3.2%	$11¾–7¼	73.1
1992[k]	525	4.2	468	277.3	33.6	188	0.8	2.2	0.21	0.30	2.6	14⅞–8	54.5
1991[k]	537	5.3	476	294.6	47.2	188	1.0	2.8	0.27	0.30	3.0	12⅝–7¾	37.3
1990[k]	498	4.4	512	310.0	64.6	190	0.9	2.3	0.22	0.30	1.9	19¼–11⅝	70.2
FMC													
1993	$3,754	$41.0[n]	$2,721	$1,390.2	$244.5	$125	1.1%	32.8%	$1.11[n]	0	—	$53–41½	42.7
1992	3,974	192.6[o]	2,763	1,502.1	314.5	156	4.8	123.5	5.04[o]	0	—	53–42⅝	9.5
1991	3,899	173.1[p]	2,753	1,484.2	216.8	247	4.4	70.1	4.68[p]	0	—	51⅝–29½	8.7
1990	3,722	155.3	2,889	1,507.1	324.3	79	4.2	196.6	4.30	0	—	38¾–25⅜	7.5
H. B. Fuller													
1993[q]	$975	$21.7[r]	$544	$232.5	$41.8	$229	2.2%	9.5%	$1.55[r]	$0.54	1.5%	$42¾–31¼	23.9
1992[q]	934	35.6	543	223.2	34.4	237	3.8	15.0	2.55	0.46	1.1	53¼–32⅝	16.8
1991[q]	853	27.7	484	207.4	30.0	194	3.2	14.3	2.00	0.41	1.4	38⅜–18⅞	14.3
1990[q]	792	21.1	468	202.3	31.5	175	2.7	12.1	1.53	0.40	2.4	19⅛–13¾	10.7
Georgia Gulf													
1993	$769	$42.2[s]	$406	$222.8	$29.6	$(111)[t]	5.5%	—	$1.01[s]	0	—	$23¾–16½	19.9
1992	779	46.3	419	211.7	14.3	(161)[t]	5.9	—	1.18	0	—	28⅝–15¾	12.7
1991	838	61.5	416	220.6	28.3	(358)[t]	7.3	—	1.75	0	—	24¾–8⅞	9.6
1990	932	95.3	457	214.7	58.1	(424)[t]	10.2	—	3.07	0	—	11–4⅞	2.6
BF Goodrich													
1993[u]	$1,818	$15.3[v]	$1,781	$836.0	$146.2	$316	0.8%	4.8%	$0.28[u]	$2.20	4.7%	$53⅞–39½	166.7
1992	2,526	(9.4)[c,w]	2,206	1,215.8	200.2	583	—	—	(0.69)[c,w]	2.20	4.5	58⅛–38⅞	—
1991	2,472	(80.6)[c]	2,038	1,171.0	211.2	989	—	—	(3.50)[c]	2.20	5.3	47⅝–36	—
1990	2,433	115.8[x]	2,198	1,109.3	243.0	1,200	4.8	9.6	4.20[x]	2.12	5.5	47⅜–29½	9.2

a Excludes net loss from early extinguishment of debt of $3.0 million ($0.06 per share) and net loss from cumulative effect of changes in accounting for health benefits for retirees of $5.8 million ($0.12 per share). **b** Excludes net loss from cumulative effect of changes in accounting for health benefits for retirees and income taxes of $9.9 million ($0.41 per share). **c** Net loss. **d** Excludes net loss from cumulative effect of changes in accounting for health benefits for retirees and for income taxes of $765.0 million ($2.82 per share). **e** Excludes net loss from early extinguishment of debt and from cumulative effect of changes in accounting for health benefits for retirees and for income taxes of $4.90 billion ($7.28 per share). **f** Excludes insurance business, spun off in 1993. In 1992, this business contributed $162.5 million to net income; spin-off reduced stockholders' equity by $677.5 million. Company data for 1992 and earlier years have not been restated. **g** Excludes extraordinary loss for early retirement of debt of $5.0 million ($0.04 per share). **h** Excludes net loss from cumulative effect of changes in accounting for health benefits for retirees and for income taxes of $14.4 million ($0.12 per share). **i** Excludes net loss from cumulative effect of changes in accounting for health benefits for retirees and income taxes of $20.5 million ($0.70 per share). **j** Excludes restructuring charge, after taxes, of $31.7 million ($1.11 per share). **k** Fiscal year ends June 30. **l** Excludes coal, oil, and certain other technology businesses discontinued in the 1992–93 fiscal year. In the year ending June 30, 1992, these businesses contributed $71.5 million to net sales and decreased net income by $11.9 million. Company data for 1992 and earlier years have not been restated. **m** From continuing operations; excludes loss from discontinued coal, oil, and other technology businesses of $26.0 million ($1.30 per share). **n** Excludes net loss for early retirement of debt of $4.7 million ($0.13 per share). **o** From continuing operations; excludes loss from discontinued operations of $73.2 million ($1.99 per share), also excludes extraordinary loss for early retirement of debt of $11.4 million ($0.31 per share) and for cumulative effect of changes in accounting for health benefits for retirees of $183.7 million ($4.99 per share). **p** Excludes extraordinary loss from refinancing debt of $9.2 million ($0.25 per share). **q** Fiscal year ends Nov. 30. **r** Excludes net loss from cumulative effect of changes in accounting for health benefits for retirees and for income taxes of $11.7 million ($0.84 per share). **s** Excludes extraordinary loss for early retirement of debt of $13.3 million ($0.32 per share) and net gain from cumulative effect of change in accounting for income taxes of $13.0 million ($0.32 per share). **t** Deficit. **u** Excludes major portion of vinyl business, spun off as a separate company in 1993. In 1992, this business contributed $894.3 million to net sales and decreased income by $79.6 million; spin-off did not affect stockholders' equity. Company data for 1992 and earlier years have not been restated. **v** From continuing operations; excludes gain from sale of vinyl business of $113.0 million ($4.40 per share). **w** Excludes net loss from cumulative effect of changes in accounting for health benefits for retirees of $286.5 million ($11.21 per share). **x** From continuing operations; excludes income from discontinued operations of $20.5 million ($0.25 per share).

FINANCES OF THE U.S. CHEMICAL INDUSTRY

(Money figures in millions of dollars unless otherwise indicated)

Year	Net sales	Net income	Total assets	Net plant and equipment	Capital expenditures	Stockholders' equity	NET INCOME			Dividend, $ per share	Dividend yield, % of price	Stock price range, $ per share	Price-earnings ratio
							% of sales	% of stockholders' equity	$ per share				
W. R. Grace													
1993	$4,408	$134.4[a]	$5,627	$1,454.1	$309.6	$1,036	3.0%	13.0%	$1.46[a]	$1.40	3.7%	$41¼–34⅝	26.0
1992	5,518	79.4[b]	5,300	1,707.9	398.4	1,246	1.4	6.4	0.88[b]	1.40	3.6	45–32	43.8
1991	6,049	219.2[c]	5,698	2,558.2	447.0	1,744	3.6	12.6	2.51[c]	1.40	4.4	40¾–23⅜	12.8
1990	6,754	202.8	5,876	2,462.1	513.7	1,562	3.0	13.0	2.36	1.40	5.5	33⅝–17	10.7
Great Lakes Chemical													
1993	$1,792	$272.8	$1,560	$468.0	$79.3	$916	15.2%	29.8%	$3.82	$0.35	0.5%	$84–64½	19.4
1992	1,496	232.7	1,432	429.8	69.4	753	15.6	30.9	3.27	0.31	0.5	71⅜–50¼	18.6
1991	1,308	157.5	1,420	405.6	71.2	672	12.0	23.4	2.23	0.27	0.6	58–30⅜	19.8
1990	1,066	140.8	1,201	363.7	48.6	538	13.2	26.2	2.00	0.23	0.9	33⅞–20⅜	13.3
Hercules													
1993	$2,773	$208.4[d]	$3,162	$1,309.3	$149.5	$1,368	7.5%	15.2%	$4.86[d]	$2.24	2.5%	$114⅞–63¼	18.3
1992	2,865	167.9	3,228	1,348.3	150.1	1,746	5.9	9.6	3.69	2.24	4.1	63¾–44⅝	14.7
1991	2,929	94.9	3,467	1,476.3	214.5	1,918	3.2	4.9	2.01	2.24	5.5	50⅜–31¾	20.4
1990	3,200	96.0	3,700	1,449.9	272.6	1,942	3.0	4.9	2.04	2.24	6.7	41½–25⅝	16.5
IMC Fertilizer Group													
1993[e]	$897	($120.0)[f,g]	$2,056	$1,326.5	$106.1	$430	--	—	($5.44)[f,g]	$0.81	2.3%	$45⅞–24⅜	—
1992[e]	1,059	90.9[h]	1,778	1,266.8	177.7	615	8.6%	14.8%	4.12[h]	1.08	2.0	68–42⅜	13.4
1991[e]	1,131	95.8	1,739	1,220.9	168.5	699	8.5	13.7	3.85	1.08	2.3	60–33	12.1
1990[e]	1,106	82.6	1,585	1,144.1	94.3	820	7.5	10.1	3.13	1.08	3.0	39¾–31⅛	11.3
International Flavors & Fragrances													
1993	$1,189	$202.4	$1,225	$323.4	$82.3	$892	17.0%	22.7%	$1.78	$1.02	3.3%	$39⅞–33	20.5
1992	1,126	176.6[i]	1,268	286.4	51.1	977	15.7	18.1	1.53[i]	0.93	2.6	38¾–31½	23.0
1991	1,017	168.7	1,217	289.6	54.1	960	16.6	17.6	1.47	0.83	2.8	35–23	19.7
1990	963	156.7	1,129	266.9	42.9	898	16.3	17.4	1.37	0.74	3.3	25–18¼	15.8
International Specialty Products													
1993	$548	$29.6	$786	$478.5	$62.9	$77	5.4%	38.4%	$0.30	$0.05	12.9%	$9¾–5¾	25.8
1992	571	57.2[j]	800	452.1	70.5	46	10.0	12.4	0.57[j]	0.05	4.0	15⅞–8¾	21.6
1991[k]	526	50.6	667	415.3	34.4	0	9.6	—	0.56	0	—	16⅛–11½[l]	28.3
Loctite													
1993	$613	$68.3	$523	$164.5	$46.3	$278	11.1%	24.6%	$1.92	$0.79	2.0%	$45⅝–34¾	20.9
1992	608	72.3	479	139.0	40.2	305	11.9	23.7	1.99	0.74	1.6	50⅞–39⅝	22.7
1991	561	71.9	447	120.6	33.5	279	12.8	25.8	1.91	0.68	1.7	50⅛–28	19.7
1990	555	67.4	458	104.0	29.4	289	12.1	23.3	1.82	0.59	2.3	30¾–20⅝	13.8
Lubrizol													
1993	$1,518	$85.0[m]	$1,146	$437.6	$127.9	$696	5.6%	12.2%	$1.25[m]	$0.85	2.7%	$36⅜–26⅝	25.2
1992	1,545	124.6	1,112	375.6	95.8	804	8.1	15.5	1.81	0.81	2.7	34⅞–24⅝	16.4
1991	1,468	123.7	1,154	380.0	82.4	777	8.4	15.9	1.78	0.77	3.0	29¾–22	14.5
1990	1,445	127.1[n]	1,097	353.6	77.4	718	8.8	17.7	1.77[n]	0.73	3.6	24½–16½	11.5
Monsanto													
1993	$7,902	$494.0	$7,451	$2,802.0	$437.0	$1,666	6.3%	29.7%	$4.10	$2.30	3.7%	$75–48⅞	15.1
1992	7,763	(126.0)[f,o]	8,019	3,005.0	586.0	1,939	—	—	(101)[f,o]	2.20	3.6	71¼–49¾	—
1991	8,864	296.0[p]	7,937	3,362.0	591.0	2,364	3.3	12.5	2.33[p]	2.045	3.4	76–46	26.2
1990	8,995	546.0[q]	7,811	3,492.0	750.0	2,664	6.1	20.5	4.23[q]	1.88	3.8	60⅛–38¾	11.7
Morton International													
1993[e]	$2,310	$126.9[r]	$1,894	$914.3	$201.4	$856	5.5%	14.8%	$2.57[r]	$0.96	1.5%	$79⅜–50¾	25.3
1992[e]	2,044	144.5	1,755	835.2	200.1	867	7.1	16.7	2.95	0.96	1.6	64⅞–51¾	19.8
1991[e]	1,906	138.3	1,563	722.3	163.6	741	7.3	18.7	2.85	0.94	2.0	57⅜–35⅝	16.3
1990[e]	1,639	129.0[s]	1,448	646.2	113.3	642	7.9	20.1	2.68[s]	0.86	2.3	44¾–31½	14.2
Nalco Chemical													
1993	1,389	$152.7[t]	$1,212	$558.5	$117.8	$438	11.0%	34.9%	$1.88[t]	$0.885	2.6%	$37⅞–30¼	18.1
1992	1,375	145.0	1,232	533.3	131.0	458	10.5	31.7	1.90	0.84	2.4	40⅞–30⅜	18.8
1991	1,237	134.6[u]	1,186	493.6	136.8	390	10.9	34.5	1.78[u]	0.83	2.4	42¼–26⅛	19.2
1990	1,212	131.1	992	419.3	114.9	410	10.8	31.9	1.71	0.755	2.9	30⅝–22	15.4

a From continuing operations; excludes loss from disposal of cocoa, battery separators, certain engineered materials, and other businesses of $108.4 million ($1.18 per share). **b** From continuing operations; excludes net loss from discontinued operations of $183.9 million ($2.05 per share) and net loss from cumulative effect of changes in accounting for health benefits for retirees of $190.0 million ($2.12 per share). **c** From continuing operations; excludes net loss from discontinued operations of $0.6 million ($0.01 per share). **d** Excludes losses from early retirement of debt and from cumulative effect of changes in accounting for health benefits to retirees and for income taxes of $241.8 million ($5.63 per share). **e** Fiscal year ends June 30. **f** Net loss. **g** Excludes net loss from cumulative effect of changes in accounting for health benefits for retirees of $47.1 million ($2.13 per share). **h** Excludes net loss from cumulative effect of changes in accounting for income taxes of $165.5 million ($4.12 per share). **i** Excludes net loss from cumulative effect of changes in accounting for health benefits for retirees and for income taxes of $6.1 million ($0.16 per share). **j** Excludes net loss from cumulative effect of changes in accounting for health benefits for retirees of $7.1 million ($0.07 per share). **k** Became a publicly held company June 21, 1991; prior to that was part of GAF; data for earlier part of 1991 are pro forma. **l** From June 21 only. **m** Excludes net loss from cumulative effect of changes in accounting for health benefits for retirees and for income taxes of $39.4 million ($0.58 per share), but includes special charge for shutting down certain manufacturing units and reducing personnel of $36.3 million ($0.83 per share) and a gain from the sale of Genentech stock of $42.4 million ($0.41 per share). **n** From continuing operations; excludes gain, after taxes, on sale of Genentech stock of $62.9 million ($1.79 per share) but includes charge for write-off of inventories and receivables due from a former affiliate of $9.7 million. **o** From continuing operations; excludes income and gain from sale of Fisher Controls of $578.0 million ($4.68 per share) and net loss from cumulative effect of changes in accounting for health benefits for retirees and for income taxes of $658.0 million ($4.38 per share). **p** Includes net restructuring expense of $325.0 million ($2.54 per share). **q** Includes net gain on divestitures of $56 million ($0.43 per share). **r** Excludes net loss from cumulative effect of changes in accounting for health benefits for retirees and future costs of disability benefits of $94.4 million ($1.91 per share). **s** Excludes extraordinary net gains of $5.8 million ($0.12 per share). **t** Excludes net losses from retirement of debt of $10.6 million ($0.15 per share) and from cumulative effect of change in accounting for health benefits for retirees of $56.5 million ($0.81 per share). **u** From continuing operations; excludes net income from discontinued operations of $3.2 million ($0.04 per share).

Year	Net sales	Net income	Total assets	Net plant and equipment	Capital expenditures	Stockholders' equity	NET INCOME			Dividend, $ per share	Dividend yield, % of price	Stock price range, $ per share	Price-earnings ratio
							% of sales	% of stockholders' equity	$ per share				
(Money figures in millions of dollars unless otherwise indicated)													
NL Industries													
1993	$805	$(83.2)[a,b]	$1,191	$378.6	$48.0	$(280)[c]	—	—	$(1.63)[a,b]	0	—	$6⅛–3⅜	—
1992	893	(44.6)[a,d]	1,453	746.0	85.2	(165)[c]	—	—	(0.88)[a,d]	$0.35	4.1%	12⅞–4	—
1991	840	(24.0)[a,e]	1,808	738.6	195.1	(81)[c]	—	—	(0.40)[a,e]	0.60	4.8	16¾–8½	—
1990	907	93.5[f]	1,941	577.1	195.3	13	10.3%	719.2%	1.42[f]	0.60	3.5	24¾–9¼	12.0
Occidental Petroleum													
1993	$8,116	$74.0[g]	$17,123	$14,284.0	$1,083.0	$3,958	0.9%	1.9%	$0.12[g]	$1.00	5.0%	$23½–16⅞	168.2
1992	8,494	126.0[h]	17,877	14,051.0	860.0	3,440	1.5	3.7	0.41[h]	1.00	5.1	23⅛–15¾	47.4
1991	9,498	317.0[i]	15,763	11,279.0	1,007.0	4,340	3.3	7.7	1.04[i]	1.00	4.8	25⅜–16½	20.1
1990	21,694	(1,695.0)[a]	19,743	13,887.0	1,446.0	4,112	—	—	(5.82)[a]	2.50	10.4	30¼–17¾	—
Olin													
1993	$2,423	$(92.0)[a]	$1,816	$885.0	$132.0	$482	—	—	$(4.52)[a]	$2.20	4.9%	$50½–39⅞	—
1992	2,376	55.0[j]	1,904	934.0	173.0	615	2.3%	8.9%	2.17[j]	2.20	4.8	54¾–37¼	21.2
1991	2,275	67.0[k]	1,880	899.0	·177.0	534	2.9	12.5	3.32[k]	2.20	5.0	54–33½	13.2
1990	2,592	84.0	1,760	829.0	187.0	609	3.2	13.8	4.03	2.15	4.8	60⅝–28⅛	10.7
Praxair[l]													
1993	$2,438	$143.0[m]	$3,188	$2,273.0	$240.0	$568	5.9%	25.2%	$1.06[m]	$0.25	1.5%	$18¼–15	15.7
1992	2,604	84.0[n]	3,283	2,315.0	333.0	483	3.2	17.4	0.64[n]	0.25[o]	1.6[o]	17⅛–13⅝[p]	24.0[o]
1991	2,469	107.0	3,417	2,338.0	417.0	616	4.3	17.4	—	—	—	—	—
Rohm and Haas													
1993	$3,269	$126.0[q]	$3,394	$1,869.0	$382.0	$1,311	3.9%	9.6%	$1.74[q]	$1.36	2.5%	$62–47¼	31.4
1992	3,063	174.0[r]	3,297	1,768.0	283.0	1,280	5.7	13.6	2.53[r]	1.28	2.5	59⅝–42¾	20.2
1991	2,763	163.0	2,867	1,470.0	265.0	1,201	5.9	13.6	2.45	1.24	3.1	48½–32¾	16.6
1990	2,824	207.0[s]	2,645	1,390.0	412.0	1,176	7.3	17.6	3.10[s]	1.22	4.0	37–24¼	9.9
Sigma-Aldrich													
1993	$739	$107.2[t]	$753	$257.3	$75.2	$591	14.5%	18.1%	$2.15[t]	$0.30	0.6%	$58–44½	23.8
1992	654	95.5	616	188.3	30.9	512	14.6	18.7	1.92	0.26	0.5	59¼–41¾	26.3
1991	589	79.8	597	191.7	26.1	441	13.5	18.1	1.60	0.23	0.6	53–28	25.3
1990	529	71.2	546	192.4	32.5	368	13.5	19.3	1.44	0.205	0.7	35⅜–25⅜	21.1
Stepan													
1993	$439	$10.8	$300	$168.9	$25.4	$104	2.5%	10.4%	$1.92	$0.81	2.6%	$37⅝–25⅛	16.3
1992	436	10.4[u]	297	167.9	34.4	100	2.4	10.4	1.91[u]	0.74	2.1	45¾–26¼	18.8
1991	414	12.5	271	157.1	33.7	91	3.0	13.8	2.30	0.66	2.6	29¾–21⅜	11.1
1990	390	14.5	247	143.3	38.4	83	3.7	17.5	2.64	0.58	2.6	27¼–16⅝	8.3
Sterling Chemicals													
1993[v]	$519	$(5.4)[a]	$482	$314.3	$12.2	$13	—	—	$(0.10)[a]	$0.06	1.5%	$5–3⅛	—
1992[v]	431	4.5[w]	536	343.8	16.0	24	1.0%	18.8%	0.08[w]	0.245	4.2	5⅛–3⅞	71.9
1991[v]	543	36.8	361	230.6	34.4	112	6.8	32.8	0.67	0.65	11.2	7⅛–4½	8.7
1990[v]	506	59.1	352	216.0	19.9	108	11.7	54.6	1.07	1.00	14.4	8⅝–5¼	6.5
Union Carbide													
1993	$4,640	$165.0[x]	$4,645	$2,420.0	$395.0	$1,384	3.6%	11.9%	$1.00[x]	$0.75	3.8%	$23⅛–16	19.6
1992	4,872	119.0[y]	4,856	2,539.0	359.0	1,153[z]	2.4	10.3	0.76[y]	0.875[z]	6.3	17⅛–10⅞	18.4
1991[aa]	4,877	(116.0)[a]	6,705	2,499.0	400.0	2,118	—	—	(1.06)[a]	1.00	5.3	22⅝–15⅛	—
1990	7,621	308.0[bb]	8,587	4,325.0	744.0	2,227	4.0	13.8	2.19[bb]	1.00	5.1	24⅞–14⅛	8.9
Witco													
1993	$2,143	$19.8	$1,622	$696.5	$103.7	$496	0.9%	4.0%	$0.46	$0.94	3.3%	$32¼–24	61.1
1992	1,729	53.9[cc]	1,562	721.2	72.6	364	3.1	14.8	1.19[cc]	0.92	4.1	25½–20	19.1
1991	1,631	73.5	1,129	474.8	74.3	556	4.5	13.2	1.605	0.89	4.9	22–14½	11.4
1990	1,631	68.0	1,136	471.0	90.8	544	4.2	12.5	1.475	0.86	5.6	20–10⅞	10.4

a Net loss. **b** Excludes net loss from retirement of debt of $27.8 million ($0.55 per share) and net gain from cumulative effect of changes in accounting for marketable securities of $1.2 million ($0.02 per share). **c** Deficit. **d** Excludes extraordinary net loss from cumulative effect of changes in accounting for health benefits for retirees and other extraordinary items of $43.5 million ($0.62 per share). **e** Excludes extraordinary net gain of $7.5 million ($0.13 per share). **f** Excludes extraordinary net loss of $1.1 million ($0.02 per share). **g** From continuing operations; excludes net income from sale of coal business of $221 million ($0.72 per share); also excludes net loss from early retirement of debt of $12 million ($0.04 per share). **h** From continuing operations; excludes net loss from discontinued coal business of $622 million ($2.06 per share); also excludes loss from early retirement of debt of $2 million ($0.01 per share) and from cumulative effect of changes in accounting for health benefits for retirees and for income taxes of $93 million ($0.31 per share). **i** From continuing operations; excludes extraordinary gain on sale of agricultural business of $143 million ($0.48 per share). **j** Excludes net loss from cumulative effect of changes in accounting for health benefits for retirees and for income taxes of $46.0 million ($2.11 per share). **k** Excludes special charge for restructuring of operations of $80 million ($4.24 per share). **l** Became an independent company on June 30, 1992; prior to that was part of Union Carbide; data for 1991 and the first half of 1992 are pro forma and are not included in Union Carbide data. **m** Excludes net loss from cumulative effect of change in accounting for future severance benefits for employees of $25 million ($0.19 per share). **n** Excludes net loss from cumulative effect of changes in accounting for health benefits of retirees and for income taxes of $144 million ($1.10 per share). **o** On full-year basis. **p** From June 30 only. **q** Excludes net loss from cumulative effect of changes in accounting for future costs of disability benefits of $19 million ($0.28 per share). **r** Excludes net loss from cumulative effect of changes in accounting for health benefits for retirees of $179.0 million ($2.69 per share). **s** Includes net gain on sale of surfactant and alkylphenol businesses of $26 million ($0.39 per share), on sale of forest property of $20 million ($0.20 per share), and net loss for write-off of intangible assets in electronic materials business of $187 million ($0.27 per share). **t** Excludes net loss from cumulative effect of changes in accounting for health benefits for retirees and for income taxes of $10.8 million ($0.22 per share). **u** Excludes net gain from changes in accounting for income taxes and investment tax credits of $5.4 million ($1.02 per share). **v** Fiscal year ends Sept. 30. **w** Excludes net loss from changes in accounting for health benefits for retirees of $10.4 million ($0.19 per share). **x** Excludes net loss from cumulative effect of changes in accounting for future severance benefits for employees of $87 million ($0.64 per share). **y** From continuing operations; excludes net gain from spin-off of industrial gases business of $67.0 million ($0.51 per share) and net loss from cumulative effect of changes in accounting for health benefits for retirees and for income taxes of $361.0 million ($2.73 per share). **z** On June 30, stockholders received one share in the newly formed industrial gases company Praxair for every share of Union Carbide stock; the effect of this spin-off was to reduce Union Carbide stockholders' equity by $733.0 million. **aa** Excludes industrial gases business, spun off during 1992. **bb** Includes net loss from sale of 50% interest in carbon product business of $86 million ($0.61 per share) and net gain from sale of other businesses of $80 million ($0.57 per share). **cc** Excludes net loss from cumulative effect of changes in accounting for health benefits for retirees and for income taxes of $14.7 million ($0.59 per share).

2 FINANCES OF THE U.S. CHEMICAL INDUSTRY

(Money figures in millions of dollars unless otherwise indicated)

Year	Net sales	Net income	Total assets	Net plant and equipment	Capital expenditures	Stockholders' equity	NET INCOME			Dividends, $ per share	Dividend yield, % of price	Stock price range, $ per share	Price-earnings ratio
							% of sales	% of stockholders' equity	$ per share				
PHARMACEUTICALS													
Abbott Laboratories													
1993	$8,408	$1,399.1	$7,689	$3,511.0	$952.7	$3,675	16.6%	38.1%	$1.69	$0.68	2.5%	$30⅞–22⅝	15.8
1992	7,852	1,239.1	6,941	3,099.2	1,007.2	3,348	15.8	37.0	1.47	0.60	2.0	34⅛–26⅛	20.5
1991	6,877	1,088.7[a]	6,255	2,662.1	770.6	3,203	15.8	34.0	1.28[a]	0.50	1.8	34¾–19⅝	21.3
1990	6,159	965.8	5,563	2,375.8	641.4	2,834	15.7	34.1	1.11	0.42	2.2	23¼–15⅝	17.5
American Cyanamid													
1993[b]	$4,277	($163.7)[c,d]	$5,752	$1,770.3	$305.5	$1,062	—	—	($1.82)[c,d]	$1.725	3.3%	$59¼–46	—
1992	5,268	395.1	5,209	2,119.8	410.0	2,518	7.5%	15.7%	4.35	1.61	2.7	66⅜–52⅛	13.6
1991	4,986	358.8	4,838	2,018.9	392.1	2,387	7.2	15.0	3.85	1.46	2.5	69–48½	15.3
1990	4,570	107.8[e]	4,864	1,906.0	375.5	2,335	2.4	4.6	1.15[e]	1.35	2.2	61½–42	5.3
American Home Products													
1993	$8,305	$1,469.3	$6,971	$2,059.8	$517.9	$3,160	17.7%	46.5%	$4.73	$2.86	4.6%	$69–55½	13.2
1992	7,874	1,150.7[f]	6,433	1,777.8	428.1	2,854	14.6	40.3	3.66[f]	2.66	3.6	84¼–63¼	20.2
1991	7,079	1,375.3	5,684	1,476.8	227.9	3,046	19.4	45.2	4.36	2.375	3.6	86¼–47⅛	15.3
1990	6,775	1,230.6[g]	5,354	1,437.4	247.7	2,392	18.2	51.4	3.92[g]	2.15	4.3	55–44	12.6
Bristol-Myers Squibb													
1993	$11,413	$1,959.0	$11,910	$3,374.0	$570.0	$5,749	17.2%	34.1%	$3.80	$2.88	4.9%	$67¼–50⅞	15.5
1992	11,727	1,603.0[h]	10,651	3,141.0	647.0	5,867	13.7	27.3	3.09[h]	2.76	3.7	90⅛–60	24.3
1991	11,159	2,056.0	9,246	2,936.0	633.0	5,625	18.4	36.6	3.95	2.40	3.2	89⅜–61⅛	19.1
1990	10,300	1,748.0	9,023	2,631.0	526.0	5,226	17.0	33.4	3.33	2.12	3.6	68–50½	17.8
Johnson & Johnson													
1993	$14,138	$1,787.0	$11,317	$4,406.0	$975.0	$4,643	12.6%	38.5%	$2.74	$1.01	2.3%	$50⅜–35⅝	15.7
1992	13,753	1,625.0[i]	11,168	4,115.0	1,103.0	4,455	11.8	36.5	2.46[i]	0.89	1.7	58¾–43	20.7
1991	12,447	1,461.0	9,775	3,667.0	987.0	4,888	11.7	29.9	4.39	0.77	1.7	58⅛–32⅛	20.7
1990	11,232	1,143.0[j]	9,506	3,247.0	830.0	4,900	10.2	23.3	3.43[j]	0.655	2.1	37–25½	18.3
Eli Lilly													
1993	$6,452	$491.1[k]	$9,624	$4,200.2	$633.5	$4,164	7.6%	11.8%	$1.67[k]	$2.42	4.5%	$62–45	32.0
1992	6,167	827.6[l]	8,213	4,072.1	912.9	4,440	13.4	18.6	2.81[l]	2.20	3.0	87¾–57¾	25.8
1991	5,726	1,314.7	7,873	3,782.5	1,142.4	4,540	23.0	29.0	4.50	2.00	2.6	84⅞–69	17.1
1990	5,192	1,127.3	6,674	2,936.7	1,007.3	2,998	21.7	37.6	3.90	1.64	2.2	89¾–59⅜	19.1
Merck													
1993	$10,498	$2,166.2	$13,282	$4,894.6	$1,012.7	$3,376	20.6%	64.2%	$1.87	$1.03	2.8%	$44⅛–25⅝	19.5
1992	9,663	2,446.6[m]	10,933	4,271.1	1,066.6	4,849	25.3	50.5	2.12[m]	0.92	1.9	56⅝–40½	22.9
1991	8,603	2,121.7	9,349	3,504.5	1,041.5	4,767	24.7	44.5	1.83	0.77	1.9	55⅝–27⅜	22.7
1990	7,671	1,781.2	7,873	2,721.7	670.8	3,677	23.3	48.4	1.52	0.64	2.4	30⅜–22⅜	17.3
Pfizer													
1993	$7,478	$657.5	$9,100	$2,632.5	$634.2	$3,634	8.8%	18.1%	$2.05	$1.68	2.6%	$75⅝–52½	31.3
1992	7,230	1,093.5[n]	9,222	2,305.1	674.2	4,350	15.1	25.1	3.25[n]	1.48	1.9	87–65⅛	23.4
1991	6,950	917.1[o]	9,251	2,381.0	593.8	4,643	13.2	19.8	2.71[o]	1.32	2.1	86⅛–36¾	22.7
1990	6,406	801.2	8,553	2,109.8	547.5	4,593	12.5	17.4	2.38	1.20	3.5	40⅞–27¼	14.3
Schering-Plough													
1993	$4,341	$825.0[p]	$4,134	$1,967.7	$365.2	$1,399	19.0%	59.0%	$4.23[p]	$1.74	2.8%	$71–51¾	14.5
1992	4,056	720.4	3,967	1,748.5	403.2	1,407	17.8	51.2	3.60	1.50	2.5	70⅛–49⅞	16.7
1991	3,616	645.6	3,822	1,490.4	339.4	1,155	17.9	55.9	3.01	1.27	2.4	67⅛–40¼	17.9
1990	3,323	565.1	3,937	1,284.4	242.9	1915	17.0	29.5	2.50	1.065	2.4	50¾–37	17.6
Upjohn													
1993	$3,611	$402.5[q]	$4,816	$1,771.3	$323.5	$2,086	11.1%	19.3%	$2.19[q]	$1.48	4.9%	$35–25⅝	13.8
1992	3,639	547.2[r]	4,605	1,670.4	295.4	2,016	15.0	27.1	3.04[r]	1.42	3.8	45⅞–29⅝	12.4
1991	3,402	537.4	4,147	1,540.7	258.1	2,005	15.8	26.8	2.96	1.26	3.0	49¼–34¾	14.2
1990	3,021	458.1[s]	3,668	1,421.6	246.8	1,780	15.2	25.7	2.48[s]	1.04	2.7	44⅝–33	15.7
Warner-Lambert													
1993	$5,794	$285.0[t]	$4,514	$1,599.3	$347.1	$1,076	4.9%	26.5%	$2.11[t]	$2.28	3.4%	$76⅜–59¾	32.2
1992	5,598	643.7	3,921	1,507.1	334.3	1,372	11.5	46.9	4.78	2.04	3.0	79¼–58⅜	14.4
1991	5,059	452.8[u]	3,444	1,350.0	326.0	1,013	9.0	44.7	4.16[u]	1.76	2.4	82¼–61¾	17.3
1990	4,687	484.9	3,100	1,301.4	239.9	1,241	10.3	39.1	3.61	1.52	2.5	70⅜–49⅝	16.6

a Excludes extraordinary net gain on sale of investment in Amgen of $128.2 million ($0.15 per share). **b** Excludes chemical business, spun off in 1993. In 1992, this business contributed $1,074 million to net sales and $16.0 million to net income; spin-off reduced stockholders' equity by $52.9 million; company data for 1992 and earlier years have not been restated. **c** Net loss. **d** From continuing operations; excludes losses from chemical business, spun off in 1993, of $622.2 million ($6.92 per share); also excludes losses from cumulative effect of changes in accounting for health benefits for retirees and for income taxes of $322.6 million ($3.70 per share). **e** From continuing operations; excludes net income from discontinued operations of $245.0 million ($2.56 per share) but includes special net charge of $206.2 million ($2.15 per share) to consolidate product lines, reduce carrying costs, increase environmental remediation costs, and reduce number of employees. **f** Excludes net loss from cumulative effect of changes in accounting for income taxes and a charge for research acquired from Genetics Institute of $310.1 million ($0.99 per share). **g** Includes gain on sale of household products and depilatory businesses, before taxes, of $999.5 million. **h** From continuing operations; excludes net gain on sale of Drackett of $605.0 million ($1.17 per share) and net loss from cumulative effect of changes in accounting for health benefits for retirees of $246.0 million ($0.47 per share). **i** Excludes net loss from cumulative effect of changes in accounting for health and other benefits for retirees and for income taxes of $595.0 million ($0.90 per share). **j** Includes charge for damage to operations in Latin America of $125 million ($0.38 per share). **k** Excludes net loss from cumulative effect of change in accounting for disability benefits for former employees of $10.9 million ($0.04 per share). **l** Excludes net loss from cumulative effect of changes in accounting for health benefits for retirees and for income taxes of $118.9 million ($0.40 per share). **m** Excludes net loss from cumulative effect of changes in accounting for health and other benefits for retirees and for income taxes of $462.4 million ($0.40 per share). **n** Excludes net loss from cumulative effect of changes in accounting for health benefits for retirees and for income taxes of $282.6 million ($0.84 per share). **o** Excludes special charge for projected payments in connection with potential future Shiley C/C heart valve fractures of $195 million ($0.58 per share). **p** Excludes net loss from cumulative effect of change in accounting for health benefits for retirees of $94.2 million ($0.48 per share). **q** From continuing operations; excludes earnings from and gain from sale of discontinued agricultural chemical business of $8.8 million ($0.04 per share); also excludes net loss from cumulative effect of several accounting changes of $18.9 million ($0.10 per share). **r** Excludes net loss from cumulative effect of changes in accounting for health benefits for retirees and for income taxes of $223.0 million ($1.26 per share). **s** From continuing operations; excludes loss on discontinued operations and their disposal of $2.4 million ($0.01 per share) but includes partial pension settlement net gain of $37.8 million. **t** Excludes net gain from cumulative effect of changes in accounting for disability benefits of former employees and income taxes of $46.0 million ($0.34 per share) but includes nonrecurring restructuring costs of $525.2 million. **u** Excludes nonrecurring net charges for restructuring of $418.0 million ($3.11 per share) and for cumulative effect of accounting change of $106.0 million ($0.79 per share).

Chemical employment tumbled in 1993

Four years of falling earnings and sliding profit margins took their toll on employment in the U.S. chemical industry in 1993. After actually increasing through much of the 1991–92 recession, chemical employment started to slip in the early months of last year. By August, staff cuts had become widespread in the chemical industry, as companies scrambled—usually successfully—to make 1993 more profitable than 1992.

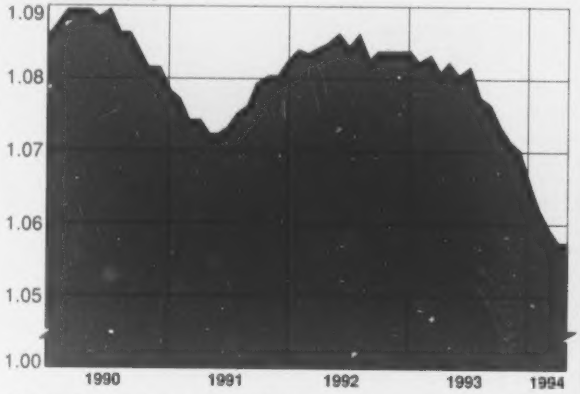
By April 1994, after nine consecutive months of decline, the chemicals and allied products industry set a six-year employment low of a seasonally adjusted 1.057 million, according to figures from the Department of Labor. Preliminary figures for May show that level unchanged, the first indication that the slide may have ended.

If so, the industry's most recent downsizing leaves it with 29,000 fewer employees than it had in August 1992. About 14,000 of those jobs were lost in 1993, most of the rest came in the early months of 1994.

As is usually the case in downsizings, job loss in 1993 was not uniform throughout the chemical industry. It was greatest at the big commodity chemical makers, particularly those that produce industrial organic chemicals and polymers. Total employment at 22 of the largest of these firms fell more than 28,000 in 1993. These companies alone cut many more jobs than did the industry as a whole, and thus the total industry decline would have been larger had not other parts of the industry added to their work force. The biggest gainers, by far, were pharmaceutical companies, which increased their employment 3% during 1993. That growth may have ended, however; drug industry employment held steady through the early months of 1994.

Just what these trends mean for chemists and engineers is uncertain. The National Science Foundation, which keeps track of the number of scientists and engineers in the chemical and other industries, has yet to release 1993 data. NSF expects to do so later this summer. As of January 1992, NSF's latest available survey, more than 82,000 scientists and engineers were working in the chemicals and allied products industries, almost 45% of them at drug firms. At that time, science and engineering employment at drug companies was 8% higher than the previous year; it was 6% lower at industrial chemical companies.

By April 1994, jobs in chemical industry had dropped 3% from their 1992 high



[a] Seasonally adjusted employment in U.S. chemicals and allied products industry; April and May 1994 figures are preliminary. **Source:** Department of Labor

INDUSTRIAL EMPLOYMENT: Drug firms grew in 1993 but chemicals, all industry downsized

Thousands	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	% annual change 1992–93	% annual change 1983–93
All manufacturing	18,432	19,372	19,248	18,947	18,999	19,314	19,391	19,076	18,406	18,040	17,802	−1%	0%
Chemicals & allied products	1,043	1,049	1,044	1,021	1,025	1,057	1,074	1,086	1,076	1,083	1,074	−1	0
Industrial inorganic chemicals	151	143	143	135	131	133	135	138	129	136	135	−1	−1
Plastics materials & synthetics	177	178	172	168	158	177	182	180	178	173	166	−4	−1
Drugs	201	206	206	208	215	228	232	237	247	257	265	3	3
Soap, cleaners & toilet goods	142	146	148	146	152	159	160	159	155	154	157	2	1
Paints & allied products	60	62	63	63	63	63	62	61	58	58	58	0	0
Industrial organic chemicals	163	162	160	154	148	146	150	155	155	154	151	−2	−1
Agricultural chemicals	61	61	59	54	51	52	54	56	57	58	56	−3	−1
Miscellaneous chemical products	89	92	94	93	97	100	99	100	97	94	92	−2	0
Petroleum & coal products	196	189	179	169	164	160	156	157	160	158	151	−4	−2
Rubber & miscellaneous plastics products	743	813	818	823	842	866	888	888	862	872	886	2	2

Note: Average annual domestic employment. **Source:** Department of Labor

PRODUCTION WORKERS: Declines of recent years halted in 1993 in most chemical fields

Thousands	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	% annual change 1992–93	% annual change 1983–93
All manufacturing	12,528	13,280	13,084	12,864	12,952	13,193	13,230	12,947	12,434	12,241	12,143	–1%	–1%
Chemicals & allied products	579	583	578	568	575	596	603	600	580	567	568	0	0
Industrial inorganic chemicals	77	73	72	69	67	69	70	70	64	61	58	–5	–2
Plastics materials & synthetics	115	117	114	113	111	116	119	116	110	104	104	0	–1
Drugs	98	96	95	96	99	101	102	105	109	112	117	4	2
Soap, cleaners & toilet goods	89	93	93	93	97	102	101	98	95	94	96	2	1
Paints & allied products	29	30	31	30	31	31	32	31	30	30	30	0	0
Industrial organic chemicals	84	82	82	81	83	86	88	86	81	76	78	3	–1
Agricultural chemicals	37	38	37	33	32	33	34	34	34	35	33	–6	–1
Miscellaneous chemical products	51	54	54	53	55	58	59	59	58	56	54	–4	1
Petroleum & coal products	118	111	109	106	107	104	102	103	103	103	99	–4	–2
Rubber & miscellaneous plastics products	574	633	632	639	654	675	694	689	663	678	685	1	2

Note: Average annual domestic employment. **Source:** Department of Labor

EMPLOYMENT OF WOMEN: Decade brings greater numbers to all chemical fields

	1982		1992	
	Thousands	% of total	Thousands	% of total
All manufacturing	5,990.0	32%	5,942.0	33%
Chemicals & allied products	279.2	26	334.6	31
Industrial inorganic chemicals	25.2	16	30.3	22
Plastics materials & synthetics	40.4	21	40.3	23
Drugs	85.7	43	116.7	45
Soap, cleaners & toilet goods	58.4	41	68.8	44
Paints & allied products	11.6	19	12.0	21
Industrial organic chemicals	27.4	16	31.5	21
Agricultural chemicals	10.0	15	10.4	18
Miscellaneous chemical products	20.5	23	24.7	26
Petroleum & coal products	31.0	15	26.1	16
Rubber & miscellaneous plastics products	247.8	34	298.2	34

Note: Average annual domestic employment. **Source:** Department of Labor

WORKWEEK: Unchanged for chemicals overall, shorter at drug companies

Hours	1990	1991	1992	1993
All manufacturing	40.8	40.7	41.0	41.4
Chemicals & allied products	42.6	42.9	43.1	43.1
Industrial inorganic chemicals	42.9	43.6	43.5	43.8
Plastics materials & synthetics	42.5	42.6	43.8	44.1
Drugs	41.8	42.5	42.5	41.4
Soap, cleaners & toilet goods	40.8	40.9	41.3	41.9
Paints & allied products	41.9	41.8	41.6	42.2
Industrial organic chemicals	45.2	45.6	45.6	45.4
Agricultural chemicals	44.1	44.4	44.5	44.7
Miscellaneous chemical products	42.4	42.3	42.6	42.8
Petroleum & coal products	44.6	44.1	43.8	44.2
Rubber & miscellaneous plastics products	41.1	41.1	41.7	41.8

Note: For production workers in domestic employment. **Source:** Department of Labor

EMPLOYMENT OF SCIENTISTS, ENGINEERS: Gains at drug firms, losses elsewhere in 1992

Thousands	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Total, all industry	509.8	540.9	584.1	622.5	671.0	695.8	708.6	720.2	730.9	704.1	683.7
Chemicals & allied products	61.6	67.3	69.8	71.1	75.8	75.2	75.8	77.6	78.9	78.8	82.2
Drugs & medicines	25.6	28.2	30.8^b	30.8	31.8	32.6	33.0	34.0	33.5	34.2	36.9
Industrial chemicals	25.9	26.6	25.6	23.5	24.9	22.4^b	22.5^b	23.1^b	23.0^b	22.7^b	21.4^b
Other chemicals	10.1	12.1	13.4	16.7	19.1	20.2	20.3	20.5	22.4	21.9	23.9
Petroleum refining & extraction	15.6	14.7	13.3	13.5	10.4	9.9	9.5	10.3	10.2	10.0	9.7

Note: Full-time equivalent number of R&D scientists and engineers in industry, as of January of each year. **b** Partly estimated. **Source:** National Science Foundation

CHEMICAL EMPLOYMENT: More than 28,000 jobs cut at major firms in 1993

Thousands	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
Air Products	16.7	17.7	18.7	16.6	12.1	13.3	14.1	14.0	14.6	14.5	14.1
Betz Laboratories	2.3	2.5	2.5	2.6	2.0	3.1	3.4	3.7	4.0	4.2	4.1
Cabot	7.2	7.5	7.7	6.6	5.1	5.2	5.5	6.0	5.3	5.4	5.4
Crompton & Knowles	2.4	2.3	2.3	1.3	1.3	1.6	1.7	1.8	2.0	2.2	2.3
Dow Chemical	54.5	49.8	53.2	51.3	53.1	55.5	62.1	62.1	62.2	61.4	55.4
Ethyl	13.0	11.0	10.5	10.5	10.0	10.4	5.5	5.7	6.0	6.3	5.5
H. B. Fuller	4.1	4.3	4.4	4.5	4.6	5.2	5.5	5.6	5.6	5.8	6.0
BF Goodrich	29.4	28.8	26.2	11.9	12.0	12.3	11.9	14.7	14.4	13.4	13.4
W. R. Grace	95.5	102.6	116.9	41.4	39.4	45.7	46.4	49.0	46.6	44.1	34.0
Hercules	24.2	26.3	25.4	25.1	23.2	22.7	23.3	19.9	17.3	15.4	14.1
International Flavors	3.7	3.7	3.7	3.8	4.1	4.2	4.2	4.2	4.2	4.2	4.4
Loctite	2.4	2.5	2.6	2.9	3.2	3.3	3.5	3.7	3.6	3.7	4.0
Lubrizol	4.2	4.2	5.2	4.8	4.8	4.8	5.3	5.2	5.3	4.6	4.6
Monsanto	48.8	50.8	56.1	51.7	49.7	45.6	42.2	41.1	39.3	33.8	30.0
Nalco Chemical	4.6	4.8	5.1	4.9	5.1	5.4	5.5	5.9	6.8	6.7	6.8
Olin	18.2	17.8	14.9	13.2	14.1	16.4	15.4	15.2	14.4	13.5	12.4
PPG Industries	37.0	37.7	37.5	36.5	36.8	36.3	35.5	35.1	33.7	32.3	31.4
Praxair[a]	—	—	—	—	—	—	—	—	—	18.6	16.8
Rohm and Haas	11.4	11.9	11.8	12.1	12.0	12.4	13.0	12.9	12.9	13.8	13.0
Stepan	0.9	0.9	0.9	0.9	1.0	1.0	1.2	1.3	1.3	1.3	1.3
Union Carbide	99.5	98.4	91.5	50.3	43.1	44.0	46.0	38.8	36.7	15.1	13.1
Witco	8.2	8.5	8.1	8.0	7.8	7.6	7.4	7.3	6.9	8.4	8.2
TOTAL EMPLOYEES	**488.2**	**494.0**	**505.2**	**360.9**	**344.5**	**356.0**	**358.6**	**353.2**	**343.1**	**328.7**	**300.3**
ANNUAL CHANGE	—	**1.2%**	**2.3%**	**–28.6%**	**–4.5%**	**3.3%**	**0.7%**	**–1.5%**	**–2.9%**	**–4.2%**	**–8.6%**
SALES PER EMPLOYEE ($ thousands)	**$112.4**	**$117.5**	**$104.4**	**$143.7**	**$169.3**	**$191.9**	**$200.1**	**$213.1**	**$204.0**	**$222.3**	**$232.6**

Note: Data are not restated for acquisitions, divestitures, or similar developments. a Spun off from Union Carbide in 1992. **Source:** Company data

WAGES: Rising for chemical production workers except at plastics makers

	Hourly earnings				Weekly earnings			
	1990	1991	1992	1993	1990	1991	1992	1993
All manufacturing	$10.83	$11.18	$11.46	$11.76	$441.86	$455.03	$469.86	$486.86
Chemicals & allied products	13.54	14.04	14.51	14.84	576.80	602.32	625.38	639.60
Industrial inorganic chemicals	14.66	15.05	15.73	16.42	628.91	656.18	684.26	719.20
Plastics materials & synthetics	13.97	14.79	15.37	15.26	593.73	630.05	673.21	672.97
Drugs	12.90	13.49	14.11	14.70	539.22	573.33	599.68	608.58
Soap, cleaners & toilet goods	11.71	12.02	12.00	12.31	477.77	490.42	494.40	515.79
Paints & allied products	11.99	12.48	12.67	12.69	502.38	521.66	527.07	535.52
Industrial organic chemicals	15.97	16.54	17.29	17.67	721.84	754.22	788.42	802.22
Agricultural chemicals	13.73	14.22	14.83	15.11	605.49	632.79	662.90	675.42
Miscellaneous chemical products	12.28	12.61	13.06	13.49	520.67	533.40	556.36	577.37
Petroleum & coal products	16.24	17.04	17.91	18.55	722.30	751.46	784.46	819.91
Rubber & miscellaneous plastics products	9.76	10.07	10.37	10.60	401.14	413.88	432.43	443.08

Note: For production workers in domestic employment. **Source:** Department of Labor

Chemical productivity rose 2.3% last year

Productivity increased in the U.S. chemical industry last year, marking the 11th straight year that it has done so. But wages for production workers in the chemical industry rose as well. In a sense, they canceled each other out, leaving the costs associated with producing each unit of product unchanged from 1992 levels.

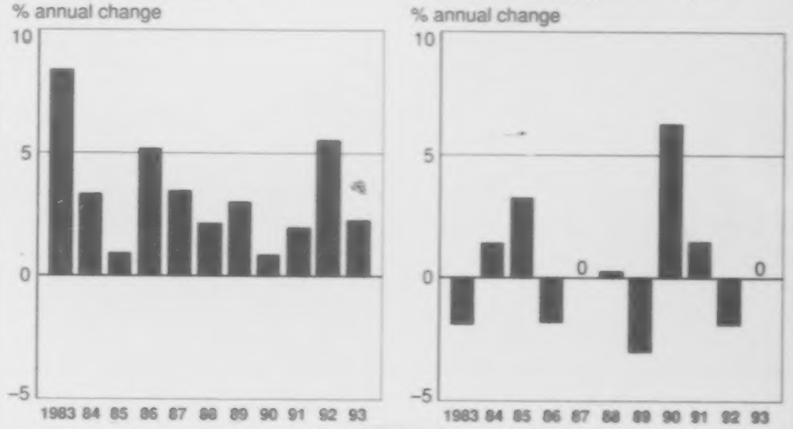
Based on data from the Department of Labor and the Federal Reserve Board, C&EN calculates that chemical industry productivity, which measures the output of the industry for each unit of labor, increased 2.3% last year over 1992. More production, up 3.1%, coupled with only slightly longer employee workhours, up 0.7%, accounted for the increase. However, wages for production workers in the chemical industry also rose 2.3% in 1993, exactly matching the productivity gain and leaving unit labor costs unchanged.

The productivity improvement for the chemical industry was just half that for all manufacturing, which rose 4.6% last year. This growth came on a 4.6% rise in output and no change in workhours. And because productivity increased much faster than the 2.6% rise in hourly production wages, unit labor costs for all manufacturing fell 2.0% for the year.

Although taken by itself, the productivity improvement for chemicals last year was not bad, it pales when compared with the annual increase in the previous year. In 1992, productivity for chemicals rose 5.5% on a much lower production increase of 2.7%. That growth came largely from reducing the work force; for the chemical industry as a whole, workhours declined 2.7% in 1992.

Chemical productivity continued to rise . . .

. . . and unit labor costs were unchanged last year



Sources: Federal Reserve Board, Department of Labor, C&EN estimates

PRODUCTIVITY: Increased production sparked solid productivity gain for chemicals in 1993

Indexes, 1967 = 100	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
CHEMICALS & ALLIED PRODUCTS											
Production	87.5	91.4	91.4	94.6	100.0	106.0	109.2	111.8	111.3	114.3	117.8
Workhours	99.2	100.3	99.4	97.8	100.0	103.8	103.8	105.4	102.9	100.1	100.8
Productivity[a]	88.2	91.1	92.0	96.7	100.0	102.1	102.1	106.1	108.2	114.2	116.9
Hourly production wages	85.7	89.8	93.6	96.7	100.0	102.3	102.2	109.5	113.3	117.3	120.0
Unit labor costs[b]	97.2	98.6	101.7	100.0	100.0	100.2	100.2	103.2	104.7	102.7	102.7
ALL MANUFACTURING											
Production	80.9	89.3	91.6	94.3	100.0	104.7	106.4	106.1	103.9	106.8	111.7
Workhours	94.4	101.5	99.7	98.5	100.0	102.9	102.2	99.4	95.3	94.4	94.4
Productivity[a]	85.7	88.0	91.9	95.7	100.0	101.7	104.1	106.7	109.0	113.1	118.3
Hourly production wages	89.3	92.8	95.9	98.3	100.0	102.9	106.1	109.3	112.8	115.6	118.6
Unit labor costs[b]	104.2	105.4	104.3	102.7	100.0	101.2	101.2	101.3	103.5	102.2	100.2

Note: Data for 1988 and subsequent years have been revised; earlier years have not. a Productivity is output per workhour, calculated by dividing indexes for production by indexes for workhours of production employees. b Unit labor costs are labor costs per unit of output, calculated by dividing indexes for wages by indexes for output per workhour.
Sources: Federal Reserve Board, Department of Labor, C&EN estimates

Markets for chemicals continue to grow

The U.S. economy as a whole—and those parts of it in particular that are heavy users of chemicals—generally continued to grow in 1993. The U.S. gross domestic product rose 3.0% last year, after an adjustment for inflation, following a 2.7% increase the year before. As a result, consumers spent more on goods and services in 1993. Government figures reveal that constant-dollar personal consumption spending rose 3.3% in 1993, faster than the economy in general. This follows 2.5% growth in 1992.

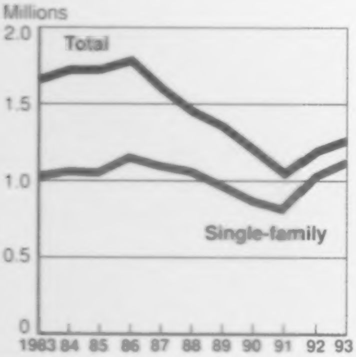
Two big end-use markets for chemicals—housing and motor vehicles—posted large and welcome increases in demand last year. The total number of housing starts was up 8% in 1993 with starts of single-family homes rising 10%, as attractive mortgage interest rates lured buyers into the market. Markets for home furnishings and home electrical appliances also rose at healthy rates in 1993, growing 6% and 16%, respectively.

Lower interest rates also helped 1993 motor vehicle sales—passenger car factory sales grew 5%, and sales of trucks and buses jumped 19%. Much of the large increase in the truck group came from small utility vehicles and pickup trucks, according to analysts. Factory sales for all motor vehicles rose 11% in 1993.

Several other of the chemical industry's key markets showed more moderate increases last year. Among them were tires, paper and paperboard, plastic products, textile mill products, and steel production.

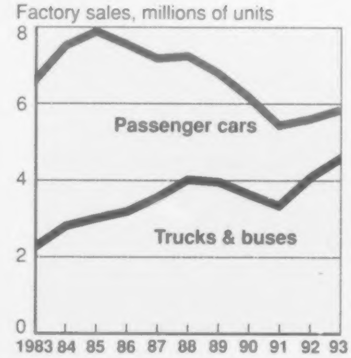
On the downside were apparel, which slipped 1%, and aluminum, down 8%. Crop production—another important chemicals market—decreased 14% in 1993 as a result of poor weather conditions throughout the country, according to the Department of Agriculture.

Housing starts



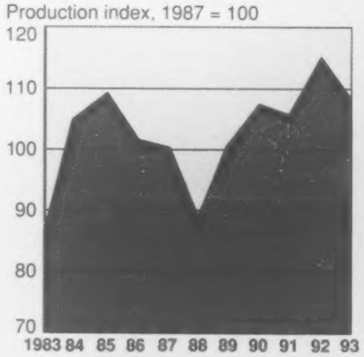
Source: Bureau of the Census

Motor vehicles



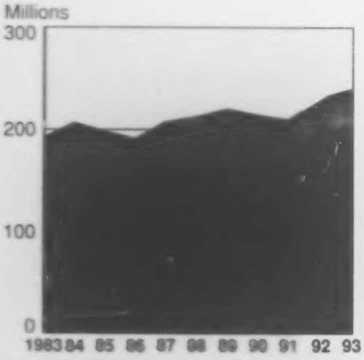
Source: Motor Vehicle Manufacturers Association

Crops



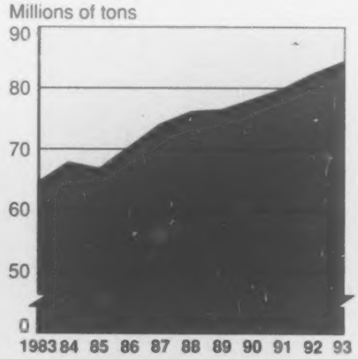
Source: Department of Agriculture

Tires and tubes



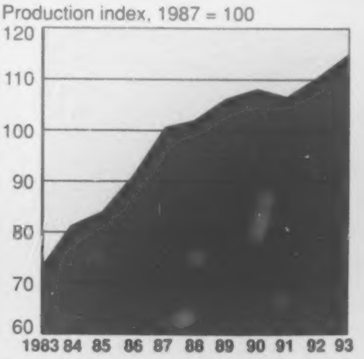
Source: Rubber Manufacturers Association

Paper and paperboard

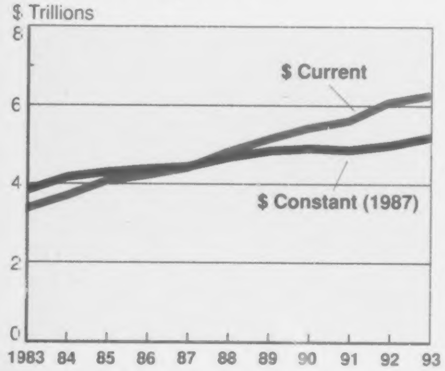


Source: American Paper Institute

Plastic products

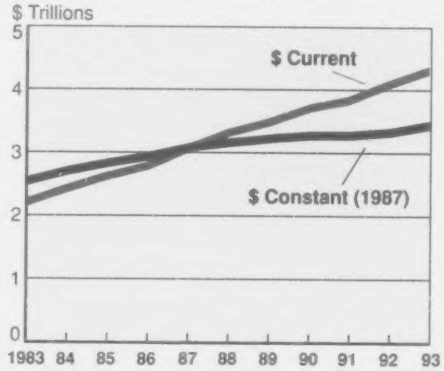


Source: Federal Reserve Board



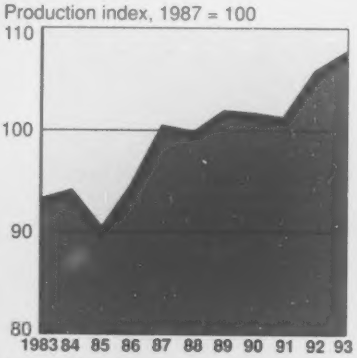
Gross domestic product

Source: Department of Commerce



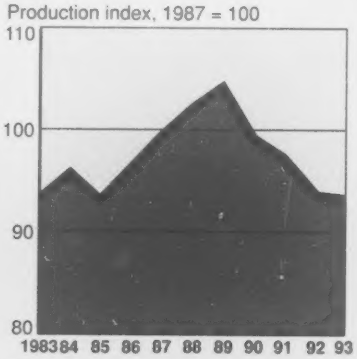
Personal consumption expenditures

Source: Department of Commerce



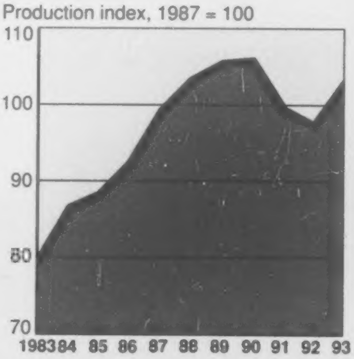
Textile mill products

Source: Federal Reserve Board



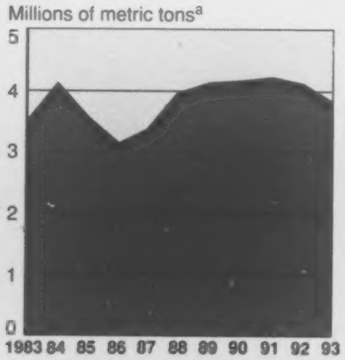
Apparel

Source: Federal Reserve Board



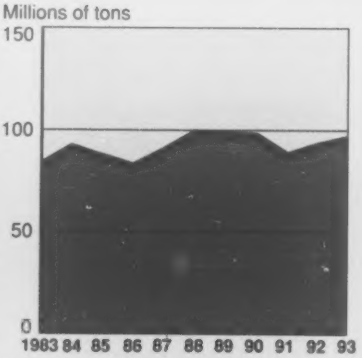
Furniture and fixtures

Source: Federal Reserve Board



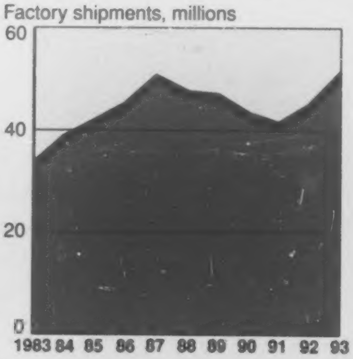
Aluminum

[a] Primary production. **Source:** Bureau of Mines



Steel

Source: American Iron & Steel Institute



Major home electrical appliances

Source: Association of Home Appliance Manufacturers

U.S. chemical exports rise slightly

Last year, U.S. chemical companies managed to boost exports 2.5% to just over $45 billion. That's not much of a gain. But considering the sad state that most of the world's economies were in during 1993, any increase at all has to be deemed quite an achievement.

It was also enough to inch the U.S. share of world chemical exports up ever so slightly, from 15.1% in 1992 to 15.2% last year. That's because the world's entire exports of chemicals rose only 2.3% to an estimated $327 billion.

Estimating world chemical exports is a tricky business at best. Exchange rates fluctuate, and different statistical sources use different rates to convert all countries' exports to dollars.

Another reason is that many countries are late in reporting their trade results. United Nations' totals for world chemical trade, for instance, are usually two years old by the time they are compiled.

This year, estimating world chemical trade is even more difficult than usual. That's because complete trade figures for the European Union (EU)—formerly the European Community (EC)—haven't been compiled for 1993. And EU member countries are among the world's largest chemical traders.

Until last year, the EC typically reported both internal (within the EC) and external (outside the EC) trade figures. Together, they provide a measure of the total chemical trade of a member country. However, when the EU completed its switch to a single market in 1993, customs controls among member countries were scrapped. As a result, the records from which internal EU trade figures were derived disappeared.

The EU itself and the European Chemical Industry Council are working to correct this statistical vacuum. At press time, however, the vacuum still existed.

So, to round out the world chemical export picture, C&EN has estimated the total chemical trade of EU member countries by taking the available external trade figures and adjusting them using recent ratios of external to internal trade figures.

U.S. TOTAL TRADE BALANCE: Deficit grew 37% last year to top $115 billion

$ Billions	1990	1991	1992	1993	% annual change 1992–93
Total exports	$394.0	$421.9	$448.2	$464.8	3.7%
Total imports	495.0	488.1	532.5	580.5	9.0
Trade balance	–101.0	–66.2	–84.3	–115.7	—

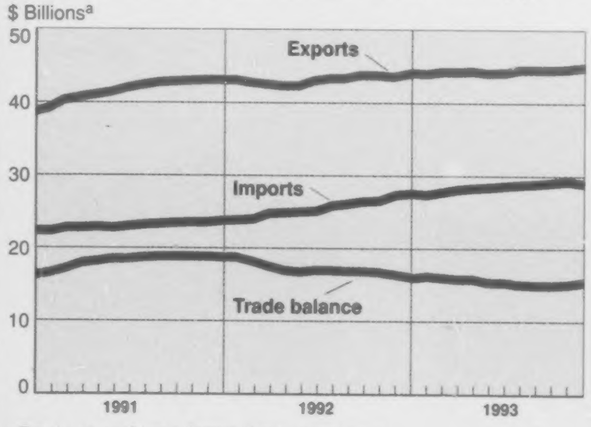
Source: Department of Commerce

U.S. CHEMICAL TRADE BALANCE: Still strongly positive, but declining

$ Millions	1990	1991	1992	1993	% annual change 1992–93
Chemical exports	$38,983	$42,967	$43,956	$45,066	2.5%
Chemical imports	22,468	24,169	27,684	29,166	5.4
Chemical trade balance	16,515	18,798	16,272	15,900	-2.3

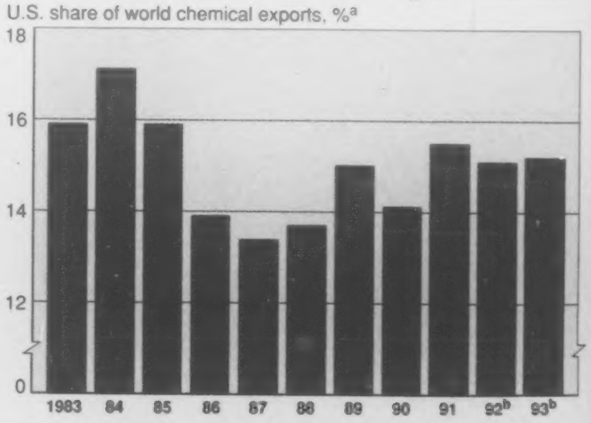
Source: Department of Commerce

U.S. chemical trade balance down in 1993 . . .



a Running 12-month totals. **Source:** Bureau of the Census

. . . but U.S. held its share of export market



a U.S. chemical exports as a percentage of total world chemical exports less U.S. chemical imports. b C&EN estimates.

U.S. CHEMICAL TRADE: Canada's share, now nearly a fifth, is fastest growing

$ Millions	1990		1991		1992		1993		% change, 1992-93	
	Exports	Imports	Exports	Imports	Exports	Imports	Exports	Imports	Exports	Imports
European Union	$10,509	$ 9,728	$11,250	$10,418	$12,050	$12,067	$11,238	$12,262	–7%	2%
Canada	6,050	4,305	6,555	4,352	7,285	4,950	8,224	5,499	13	11
Latin America	5,773	1,287	6,590	1,333	7,222	1,582	7,743	1,606	7	2
Japan	4,582	2,391	5,047	2,706	4,708	3,175	4,966	3,604	6	14
Communist Asia	1,054	337	1,671	392	1,208	509	848	591	–30	16
Rest of Asia	6,566	1,267	7,172	1,445	7,054	1,589	7,384	1,665	5	5
Australia	1,247	344	1,357	421	1,432	332	1,452	303	1	–9
Middle East	629	355	673	372	766	408	761	514	–1	26
Africa	628	90	715	95	609	108	617	132	1	22
Eastern Europe	460	242	387	263	174	270	254	418	46	55
Other	1,485	2,122	1,550	2,372	1,448	2,694	1,579	2,572	9	–5
TOTAL	**$38,983**	**$22,468**	**$42,967**	**$24,169**	**$43,956**	**$27,684**	**$45,066**	**$29,166**	**3%**	**5%**

Source: Department of Commerce

WORLD CHEMICAL TRADE: Rises slightly, despite falling imports to Europe

$ Millions	1990		1991		1992		1993		% change, 1992-93	
	Exports	Imports	Exports	Imports	Exports	Imports	Exports	Imports	Exports	Imports
European Union[a]	$164,987	$141,643	$167,342	$144,002	$177,789	$157,762	$180,767[b]	$141,963[b]	2%	–10%
Germany	50,597	30,854	51,317	32,753	54,278	34,951	52,061[b]	31,571[b]	–4	–10
France	28,339	24,965	28,839	24,394	31,433	26,348	30,677[b]	25,567[b]	–2	–3
U.K.	23,594	19,317	24,352	19,396	26,286	20,461	26,253[b]	20,101[b]	0	–2
Netherlands	22,478	13,254	21,541	13,091	22,211	14,451	23,952[b]	12,783[b]	8	–12
Belgium-Luxembourg	16,447	13,701	16,707	13,980	18,012	14,892	19,578[b]	12,881[b]	9	–14
Italy	10,920	19,860	11,350	20,110	12,508	20,968	13,052[b]	19,830[b]	4	–5
U.S.	38,983	22,468	42,967	24,169	43,956	27,684	45,066	29,166	3	5
Japan	15,872	16,045	17,475	17,412	19,118	17,355	20,199	17,964	6	4
Switzerland	13,776	8,035	13,607	7,685	15,456	8,405	15,788	8,389	2	0
Canada	6,600	7,753	6,685	8,143	7,025	9,044	7,645	10,543	9	17
WORLD	**$ 298,469**	**$298,469**	**$300,697**	**$300,697**	**$319,200**[b]	**$319,200**[b]	**$326,600**[b]	**$326,600**[b]	**2%**	**2%**

[a] Includes, in addition to the listed countries, Denmark, Greece, Ireland, Portugal, and Spain. [b] C&EN estimates.
Sources: United Nations, Organization for Economic Cooperation & Development, European Union, individual government agencies

U.S. TRADE, BY PRODUCTS: Fertilizer exports drop sharply but imports rise

$ Millions	1990		1991		1992		1993		% change, 1992-93	
	Exports	Imports	Exports	Imports	Exports	Imports	Exports	Imports	Exports	Imports
Organic chemicals	$10,400	$ 7,392	$10,928	$ 8,157	$10,993	$ 9,366	$11,090	$ 9,316	1%	–1%
Plastics in primary form	6,428	1,974	7,537	1,930	7,178	2,247	7,372	2,724	3	21
Medicinals & pharmaceuticals	4,103	2,500	4,606	3,053	5,357	3,812	5,747	4,133	7	8
Inorganic chemicals	3,816	3,234	4,102	3,299	4,119	3,300	3,813	3,285	–7	–1
Plastics in nonprimary form	2,633	1,774	2,786	1,855	3,076	2,046	3,371	2,123	10	4
Essential oils & perfume materials	1,963	1,323	2,361	1,417	2,631	1,712	3,043	1,809	16	6
Dyeing, tanning & coloring materials	1,588	1,288	1,648	1,416	1,857	1,626	2,011	1,700	8	5
Fertilizers, manufactured	2,574	955	2,980	919	2,372	952	1,798	1,135	–24	19
Other	5,478	2,028	6,020	2,123	6,363	2,623	6,821	2,941	2	12
TOTAL	**$38,983**	**$22,468**	**$42,967**	**$24,169**	**$43,956**	**$27,684**	**$45,066**	**$29,166**	**3%**	**5%**

Source: Department of Commerce

European chemicals begin slow recovery

After a serious downturn in 1992, the European chemical industry last year started on a slow path to recovery. Sales picked up in many countries, some companies that had shown losses in 1992 began making a profit again, and declines in capital investment and R&D spending slowed or actually turned up slightly.

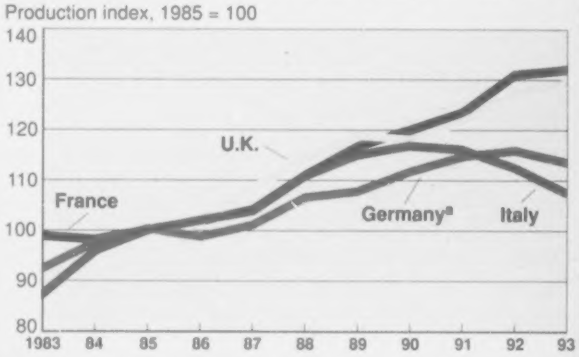
A precise picture of the chemical industry in 1993, at least in Western Europe, is difficult to obtain. Much of the region converted to a single market in 1993, the European Union, leading to changes in the way some countries collected import and export data. Additional changes occurred in Germany, which now includes the former East German states in its totals, and in the U.K., which is currently overhauling its data collection process.

Ironically, the financial recovery of the industry occurred despite a continuing slump in production of most bulk chemicals in major Western European countries. However, specialty businesses gave the industry a boost last year. That was particularly apparent for pharmaceutical companies, as the three major Swiss drugmakers—Ciba, Roche, and Sandoz—rose dramatically in the ranks of major European chemical producers in 1993.

There were some encouraging signs that the industry was repairing its profitability—or at least limiting declines—as profit margins at some companies began creeping upward. Cost-cutting measures continued, with much emphasis given to cuts in employment. According to data compiled by the European Chemical Industry Council from its member national associations, nearly 95,000 jobs were shed last year. Almost half of them were in Germany, where the chemical work force shrank by 46,100, primarily because of rationalizations and plant closures in the former East Germany. Other former East bloc countries—Poland, Hungary, the Czech Republic, and Slovakia—accounted for a net loss of 11,200 jobs, as well.

Chemical production rose slightly in much of Eastern Europe in 1993 after three years of dramatic decline. Poland's chemical output grew 10%, and several of its neighbors—including Hungary, Bulgaria, and Romania—posted more modest gains. In the former Soviet states, however, all industrial production—including chemicals—continued to plummet last year.

U.K., France posted output gains in 1993



a Former West Germany only. **Source:** European Chemical Industry Council (CEFIC)

CHEMICAL INDUSTRY TRENDS: Sales finally begin to pick up as prices rise

$ Billions (U.S.)	1989	1990	1991	1992	1993
GERMANY[a]					
Sales	$96.8	$98.5	$100.5	$103.8	$98.7
Exports	52.1	51.2	50.4	na	na
Imports	31.1	32.2	34.8	na	na
Capital spending	7.0	7.6	7.9	8.5	7.4
Production index[b]	109.4	112.4	114.8	116.0	113.5
Price index[b]	95.2	93.8	93.2	91.4	89.1
Employees (thousands)	582	592	594	655	609
FRANCE[c]					
Sales	$61.6	$61.8	$65.9	$63.9	$65.1
Exports	26.0	25.7	26.9	27.6	28.0
Imports	22.1	22.6	22.7	23.2	21.6
Capital spending	3.6	4.1	4.1	3.6	3.4
Production index[b]	118.2	120.3	122.9	130.5	132.3
Price index[b]	103.2	103.2	103.3	102.0	99.9
Employees (thousands)	264	263	264	260	255

$ Billions (U.S.)	1989	1990	1991	1992	1993
U.K.[c]					
Sales	$40.5	$42.8	$43.4	$44.9	$49.6
Exports	18.6	20.1	21.0	22.6	26.6
Imports	15.7	16.3	16.6	17.6	20.0
Capital spending	3.1	2.8	2.8	3.3	2.9
Production index[b]	119.3	118.2	121.7	126.7	130.1
Price index[b]	116.4	121.7	126.5	128.6	134.0
Employees (thousands)	323	317	306	305	293
ITALY					
Sales	$38.5	$39.3	$39.7	$40.7	$42.6
Exports	10.0	9.9	9.8	11.0	13.7
Imports	16.0	16.4	16.7	17.9	19.3
Capital spending	2.0	2.2	2.4	2.3	2.1
Production index[b]	115.0	117.1	115.8	112.2	107.5
Price index[b]	110.7	117.1	120.4	114.2	117.1
Employees (thousands)	220	217	215	208	200

$ Billions (U.S.)	1989	1990	1991	1992	1993
BELGIUM^{c,d,e}					
Sales	$26.7	$27.1	$27.5	$27.5	$27.4
Exports	20.0	20.0	20.6	21.2	na
Imports	16.5	16.8	17.4	17.6	na
Capital spending	2.0	2.6	2.7	2.2	1.5
Production index^{b}	124.9	132.3	130.0	144.1	137.5
Price index^{b}	102.1	98.8	98.1	97.5	96.9
Employees (thousands)	95	97	99	99	97
SPAIN^{c,d}					
Sales	$30.3	$32.3	$31.4	$32.1	$23.4
Exports	4.8	5.0	5.1	5.4	4.4
Imports	8.3	8.3	9.4	10.2	9.3
Capital spending	0.7	0.8	0.8	0.7	1.0
Production index^{b}	128.6	132.5	130.9	109.3	108.2
Price index^{b}	108.3	112.1	112.8	99.2	100.7
Employees (thousands)^{f}	240	240	225	129	125
NETHERLANDS					
Sales	$25.5	$25.8	$24.4	$23.3	$21.4
Exports	25.2	23.6	23.3	22.6	20.8
Imports	15.5	13.9	13.9	14.5	14.4
Capital spending	2.3	2.3	2.3	1.8	1.3
Production index^{b}	118.0	120.0	120.0	119.0	116.0
Price index^{b}	92.0	89.0	87.0	87.0	84.0
Employees (thousands)	93	93	92	89	85
SWITZERLAND^{c}					
Sales	$13.9	$14.5	$15.1	$16.2	$17.3
Exports	12.0	12.4	12.9	14.4	15.1
Imports	7.2	7.2	7.2	7.7	8.0
Production index^{b}	119.0	119.6	120.6	124.9	134.8
Price index^{b}	97.0	97.9	97.9	98.1	96.8
Employees (thousands)	72	73	72	72	72
SWEDEN					
Sales	$6.1	$6.4	$6.1	$6.3	$7.2
Exports	3.1	3.3	3.6	3.9	5.0
Imports	3.9	4.0	3.9	3.9	4.9
Capital spending	0.5	0.5	0.5	0.5	0.5
Production index^{b}	115.0	119.5	111.0	118.4	127.7
Price index^{b}	116.0	118.0	122.3	120.0	126.5
Employees (thousands)	42	41	40	37	36
IRELAND^{c}					
Sales	$3.8	$4.2	$4.7	$5.4	$5.8
Exports	3.4	3.4	3.9	4.7	5.1
Imports	2.2	2.3	2.5	2.5	2.6
Production index^{b}	144.8	149.0	175.4	212.9	225.0
Price index^{b}	96.8	92.5	91.1	92.5	99.0
Employees (thousands)	13	14	15	15	15
AUSTRIA					
Sales	$7.9	$7.8	$7.8	$7.7	$5.0
Exports	3.4	3.4	3.6	3.7	3.6
Imports	4.5	4.7	4.9	5.0	5.1
Capital spending	0.8	0.9	0.8	0.8	0.7
Production index^{g}	103.8	105.4	105.2	101.3	98.2
Employees (thousands)^{f}	57	57	54	33	31

$ Billions (U.S.)	1989	1990	1991	1992	1993
POLAND					
Sales	$2.3	$2.9	$2.4	$3.2	$5.0
Exports	0.7	0.7	0.6	0.9	1.1
Imports	0.4	0.5	0.5	1.6	2.6
Capital spending	0.2	0.2	0.2	0.3	0.3
Production index^{h}	109.8	81.6	70.6^{i}	75.4^{i}	82.6^{i}
Price index^{b}	744.9	6,078.8	26,805.0	9,905.0	12,727.0
Employees (thousands)	158	158	148	160	164
DENMARK					
Sales	$4.0	$4.0	$4.4	$4.6	$4.5
Exports	3.1	3.1	3.3	3.7	3.7
Imports	3.5	3.5	3.6	3.7	na
Capital spending	0.4	0.3	0.4	0.3	na
Production index^{b}	110.0	111.0	111.9	118.9	118.4
Price index^{b}	109.0	112.0	114.1	115.9	114.9
Employees (thousands)	27	27	27	27	28
FINLAND					
Sales	$4.0	$4.4	$3.9	$3.6	na
Exports	0.6	1.1	1.1	1.3	$1.5
Imports	1.0	1.9	1.8	2.0	2.3
Capital spending	0.4	0.5	0.4	0.2	na
Production index^{b}	120.2	116.8	109.9	108.5	109.2
Price index^{b}	107.8	109.1	110.9	114.0	116.9
Employees (thousands)	20	19	19	19	18
NORWAY					
Sales	$3.2	$3.2	$3.9	$3.1	$3.1
Exports	1.9	2.0	2.0	1.9	1.9
Imports	1.9	2.0	2.1	2.1	2.3
Capital spending	0.2	0.2	0.2	0.2	0.2
Production index^{b}	108.6	114.0	111.3	109.9	116.4
Price index^{b}	122.0	120.3	122.0	117.6	118.0
Employees (thousands)	14	15	14	12	12
HUNGARY					
Sales	$2.0	$2.1	$2.1	$2.0	$2.3
Exports	1.1	0.9	1.3	0.9	0.9
Imports	1.0	1.3	1.4	1.4	1.7
Capital spending	0.2	0.2	0.2	0.1	0.1
Production index^{b}	na	na	81.6	65.9	66.4
Price index^{b}	na	na	181.2	208.0	221.5
Employees (thousands)	76	69	70	59	57
CZECH REPUBLIC					
Sales	—	—	—	$1.8	$1.6
Exports	—	—	—	1.1	1.2
Imports	—	—	—	1.3	1.5
Production index^{h}	—	—	—	55.7	52.0
Price index^{h}	—	—	—	229.7	240.3
Employees (thousands)	—	—	—	47	44
SLOVAKIA					
Sales	—	—	—	$2.9	$2.5
Exports	—	—	—	0.5	0.9
Imports	—	—	—	0.4	0.5
Capital spending	—	—	—	0.3	0.2
Production index^{g}	—	—	—	78.0	74.0
Price index^{g}	—	—	—	221.2	216.5
Employees (thousands)	—	—	—	49	40

Note: Monetary statistics for all years are converted from local currency to U.S. dollars on the basis of 1993 conversion rates as follows: $1.00 = 11.63 Austrian schillings, 34.56 Belgian francs, 29.12 Czech crowns, 6.48 Danish crowns, 5.72 Finnish marks, 5.66 French francs, 1.65 German marks, 90.47 Hungarian forints, 0.680 Irish pounds, 1,572 Italian lire, 1.86 Netherlands guilders, 7.09 Norwegian crowns, 18,094 Polish zlotys, 33.35 Slovakian crowns, 127.2 Spanish pesetas, 7.79 Swedish crowns, 1.48 Swiss francs, and 0.670 British pounds. **a** Production and price indexes for all years are for former West Germany only; other data for 1992 and 1993 are for all of Germany; for earlier years all data are for the former West Germany only. **b** 1985 = 100. **c** Excludes fibers. **d** Includes rubber and plastics processing. **e** Includes Luxembourg for exports and imports. **f** 1991 and earlier years include plastics and rubber processing employees. **g** 1990 = 100. **h** 1989 = 100. **i** C&EN estimates. **na** = not available. **Source:** European Chemical Industry Council (CEFIC)

MAN-MADE FIBERS: Production declined in both Western and Eastern Europe in 1993

Millions of lb	1989		1990		1991		1992		1993		% change, 1992–93	
	Non-cellulosics	Cellulosics	Non-cellulosics	Cellulosics	Non-cellulosics	Cellulosics	Non-cellulosics	Cellulosics	Non-cellulosics	Cellulosics	Non-cellulosics	Cellulosics
Germany	1,841	394	1,848	396	1,779	382	1,804	360	1,797	392	0%	9%
Italy	1,412	77	1,450	79	1,482	79	1,528	71	1,378	68	–10	–4
Benelux countries	521	119	568	117	606	115	598	110	593	99	–1	–10
Spain	592	88	585	79	558	66	595	49	578	20	–3	59
U.K.	493	255	506	266	514	218	529	172	512	146	–3	–15
France	392	4	343	0	260	0	269	0	260	0	–3	—
Ireland	207	0	205	0	210	0	240	0	240	0	0	—
Switzerland	264	0	260	0	238	0	247	0	212	0	–14	—
Poland	371	152	250	79	175	57	195	49	211	51	8	4
Portugal	141	2	141	1	141	0	163	0	148	0	–9	—
Bulgaria	200	10	164	9	151	9	106	6	na	na	—	—
Romania	374	227	308	156	233	84	189	57	85	14	–55	–75
Austria	77	301	84	297	84	262	90	282	82	289	–9	3
Hungary	70	9	59	9	61	6	55	0	51	0	–7	—
Finland	7	143	11	141	24	104	24	124	24	126	0	2

na = not available. **Source:** International Rayon & Synthetic Fibers Committee

PRODUCTION: Downturns for many chemicals in France and Italy

Millions of lb	1990	1991	1992	1993	% change 1992–93
FRANCE					
Sulfuric acid	8,306	7,970	6,642	5,061	–24%
Hydrochloric acid	1,488	1,441	1,327	1,260	–5
Chlorine	2,956	2,790	3,091	3,073	–1
Sodium hydroxide	3,143	2,933	3,250	3,240	0
Carbon black	556	494	510	450	–12
Ammonia	3,493	3,526	3,097	3,263	5
Benzene	1,434	1,542	1,618	1,604	–1
Toluene	63	57	70	113	64
Ethylene	4,948	5,328	5,829	5,600	–4
Propylene	3,157	3,546	3,971	3,667	–8
Butadiene	619	623	731	706	–3
Formaldehyde	220	95	90	92	2
Polyethylene	2,461	2,643	2,954	2,930	–1
Polypropylene	1,715	1,790	1,975	2,140	8
Polystyrene	1,193	1,164	1,119	1,060	–5
Polyvinyl chloride	2,265	2,310	2,416	2,587	7
Synthetic rubber	1,151	1,036	1,098	1,070	–3
Nitrogen fertilizers	4,655	4,026	3,812	3,891	2
Phosphate fertilizers[a]	626	554	607	265[b]	–56
GERMANY[c]					
Sulfuric acid	7,370	6,800	6,974	6,691	—
Hydrochloric acid	1,982	1,851	1,857	1,819	—
Nitric acid	3,936	2,967	2,880	4,390	—
Chlorine	7,175	6,687	5,934	6,011	—
Sodium hydroxide	7,129	6,803	6,500	6,568	—
Sodium carbonate	3,166	3,029	2,760	3,490	—
Sodium sulfate	368	306	231	239	—
Carbon black	870	837	826	736	—
Ammonia	3,686	3,418	3,500	4,621	—
Benzene	3,287	3,396	3,500	3,341	—
Toluene	1,184	1,314	1,278	988	—
Xylenes	1,276	1,200	1,218	1,235	—
Aniline	294	298	315	251	—
Ethylene	6,773	6,746	7,480	8,591	—
Propylene	4,028	4,053	4,500	5,366	—
Butadiene	1,714	1,475	1,390	1,939	—
Ethylene oxide	1,386	1,310	1,390	1,371	—
Ethylene glycol	464	443	500	509	—
Propylene oxide	1,302	1,360	1,226	1,327	—
Propylene glycol	394	395	385	424	—
n-Butanol	781	767	745	696	—
Acetaldehyde	771	744	721	766	—
Acetic acid	713	707	728	749	—
Ethanol	234	239	200	342	—
Methanol	1,656	1,580	1,700	2,645	—
Formaldehyde	1,500	1,455	1,514	1,411	—
Phthalic anhydride	507	438	400	460	—
Polyethylene	3,254	3,004	3,200	3,573	—
Polyvinyl chloride	2,913	2,593	2,516	1,385	—
Polypropylene	1,121	1,170	1,300	2,661	—
Synthetic rubber	1,154	1,123	1,080	1,284	—
Nitrogen fertilizers[d]	1,816	1,404	1,400	na	—
Phosphate fertilizers[a]	165	151	106	na	—
ITALY					
Sulfuric acid	7,190	6,523	6,102	5,067	–17%
Nitric acid	2,286	2,173	2,065	1,595	–23
Hydrochloric acid	1,630	1,279	1,265	1,217	–4
Phosphoric acid	497	371	192	81[e]	–59
Chlorine	2,300	1,903	1,946	1,901	–2
Sodium hydroxide	2,427	2,300	2,123	2,055	–3
Sodium perborate	271	269	286	277	–3
Carbon black	405	408	402	377	–6
Ammonia	3,207	3,063	2,988	1,948	–35
Benzene	1,351	1,354	1,137	1,320	16
Toluene	423	410	285	431	51
Xylenes	841	875	710	325	–54
Formaldehyde	251	228	191	131	–31
Acetic acid	21	21	19	18	–5
Polyethylene	2,053	2,089	2,039	2,091	2
Polystyrene	778	684	619	602	–3
Polyvinyl chloride	1,362	1,367	1,358	1,346	–1
Nitrogen fertilizers[d]	5,261	5,062	5,802	5,017	–14
U.K.[f]					
Sulfuric acid[g]	2,847	2,478	2,170	na	—
Hydrochloric acid[g]	358	338	328	na	—
Chlorine	2,073	1,938	1,890	na	—
Sodium hydroxide[g]	2,126	2,471	1,993	na	—
Benzene	1,544	2,009	1,717	na	—
Ethylene	3,296	3,991	4,263	na	—
Propylene	1,653	1,748	1,835	na	—
Butadiene	436	436	501	na	—
Acetone	283	278	281	na	—
Formaldehyde	94	131	131	na	—
Polyethylene[h]	740	830	693	na	—
Polypropylene	653	696	721	913	27%
Polyvinyl chloride	768	712	647	539	–17
Synthetic rubber	605	554	558	485	–13

a As P_2O_5. **b** Data for 1993 are C&EN estimates based on nine months' reporting. **c** Data for 1990–92 are for the former West Germany only. 1993 data are for all Germany and are not comparable to those from earlier years. **d** As N. **e** C&EN estimates based on six months' reporting. **f** Changes in collection of U.K. data have delayed release of most 1993 figures. **g** Manufacturers' sales. **h** Excludes linear low-density polyethylene. **na** = not available. **Sources:** British Plastics Federation, British Rubber Institute, government agencies for each country

COMPANY RESULTS: About half increased income in 1993, nearly all cut staff

$ Millions	Net sales	Net income	Profit margin[a]	Capital spending	R&D spending	Employees (thousands)
Hoechst (Germany)						
1993	$27,907.3	$458.2	1.6%	$2,180.0	$1,841.8	172.5
1992	27,800.0	716.4	2.6	2,290.3	1,760.0	177.7
1991	28,597.6	1,357.0	2.9	2,162.4	1,738.8	179.3
1990	27,189.1	1,027.9	3.8	2,059.9	1,628.4	172.9
BASF (Germany)						
1993	$26,135.2	$520.0	2.0%	$2,508.5	$1,172.1	112.0
1992	26,983.3	372.5	1.4	2,515.8	1,241.5	123.2
1991	28,258.3	629.9	2.2	2,909.1	1,250.2	129.4
1990	28,256.6	671.1	2.4	2,701.9	1,253.7	134.6
Bayer (Germany)						
1993	$24,852.7	$831.5	3.3%	$1,912.7	$1,913.3	151.9
1992	24,966.7	918.8	3.7	1,732.7	1,876.4	156.4
1991	25,697.6	1,105.5	4.3	1,863.0	1,822.4	164.2
1990	25,238.2	1,140.0	4.5	2,233.9	1,659.4	171.0
ICI (U.K.)						
1993[b]	$15,964.0	$381.4[c]	2.4%	$698.2	$549.5	87.1
1992	18,109.6	(456.5)[d,e]	—	1,216.2	1,129.1	117.5
1991	18,750.8	813.8	4.3	1,331.8	944.4	128.6
1990	19,378.4	867.9[f]	4.8	1,521.0	1,019.5	132.1
Ciba (Switzerland)						
1993	$15,302.0	$1,202.0	7.9%	$1,175.0	$1,487.8	87.5
1992	15,002.7	1,027.0	6.8	1,254.7	1,567.8	90.6
1991	14,261.5	864.9	6.1	1,322.3	1,476.4	91.7
1990	13,312.8	698.0	5.2	1,390.5	1,385.8	94.1
Rhône-Poulenc (France)						
1993	$14,233.9	$325.8	2.3%	$1,097.2	$1,131.6	81.7
1992	14,436.2	385.9	2.7	1,019.8	1,053.4	83.3
1991	14,808.7	354.1	2.4	1,366.7	1,013.4	87.0
1990	13,924.1	343.2	2.5	1,325.0	936.4	91.6
Sandoz (Switzerland)						
1993	$10,202.7	$1,148.6	11.3%	$662.4	$1,182.6	52.6
1992	9,740.5	1,010.1	10.3	805.4	1,010.8	53.4
1991	9,083.8	752.7	8.3	856.8	897.3	53.4
1990	8,356.1	653.4	7.8	858.1	816.2	52.6
Roche Group (Switzerland)						
1993	$9,672.3	$1,674.3	17.3%	$950.7	$1,461.5	56.1
1992	8,752.0	1,294.6	14.8	873.6	1,350.0	56.3
1991	7,737.2	1,001.4	12.9	769.6	1,166.9	55.1
1990	6,533.8	640.5	9.8	612.8	975.7	52.7
Degussa (Germany)						
1993[g]	$9,030.9	$73.3	0.8%	$301.8	$284.2	32.1
1992[g]	7,766.7	73.3	0.9	366.7	292.1	33.4
1991[g]	8,090.9	60.0	0.7	474.5	293.3	34.5
1990[g]	8,439.4	89.0	1.1	412.7	277.6	35.0
Akzo Nobel (Netherlands)						
1993[h]	$8,875.8	$375.3[i]	4.2%	$629.0	$499.5	60.7
1992	9,059.1	393.0[j]	4.3	501.6	499.5	62.5
1991	9,059.8	365.1[k]	4.0	541.4	481.7	65.2
1990	9,272.0	384.9[l]	4.2	607.0	479.0	69.8
Norsk Hydro (Norway)						
1993	$8,794.0	$422.6	4.8%	$1,047.2	$98.7	32.5
1992	8,189.3	(27.5)[d]	—	1,076.6	100.1	30.1
1991	8,663.3	(70.2)[d]	—	1,073.6	124.3	35.0
1990	8,599.7	409.2	4.8	987.0	102.0	33.0

$ Millions	Net sales	Net income	Profit margin[a]	Capital spending	R&D spending	Employees (thousands)
Solvay (Belgium)						
1993	$7,056.2	$(114.5)[d,m]	—	$554.9	$343.8	43.2
1992	7,354.6	303.8[n]	4.1%	1,286.1	352.3	45.4
1991	7,364.2	306.7[o]	4.2	979.8	371.8	45.6
1990	7,376.9	514.5[p]	7.0	1,054.9	371.3	45.7
EniChem (Italy)						
1993	$6,761.8	$(1,695.0)[d]	—	$323.0	$137.0	30.6
1992	7,087.0	(991.1)[d]	—	747.8	195.0	33.0
1991	8,528.6	(471.4)[d]	—	857.7	251.6	37.0
1990	9,567.3	(43.1)[d]	—	1,165.2	204.6	49.0
Air Liquide (France)						
1993	$5,366.6	$393.1	7.3%	$684.8	$82.3	28.0
1992	5,175.6	392.4	7.6	604.1	81.8	28.0
1991	5,621.7	390.4	6.9	726.3	133.7	28.0
1990	5,108.6	348.3	6.8	700.6	129.6	na
BOC International (U.K.)						
1993[g]	$4,858.1	$306.2	6.3%	$617.0	$128.1	40.3
1992[g]	4,100.9	292.0[q]	7.1	592.0	121.9	37.1
1991[g]	4,081.8	290.5	7.1	640.8	95.6	39.7
1990[g]	3,969.8	358.9	9.0	462.5	93.3	40.0
DSM (Netherlands)						
1993	$4,322.6	$(32.3)[d,r]	—	$399.5	$209.7	20.6
1992	4,788.7	120.4	2.5%	573.1	228.5	22.4
1991	5,025.3	277.4	5.5	944.1	228.5	24.8
1990	5,464.5	436.0[s]	8.0	704.3	228.5	24.9
Schering Group (Germany)						
1993	$3,250.3	$153.9	4.7%	$280.6	$588.5	23.3
1992	3,798.4	159.4	4.2	417.6	599.4	26.0
1991	3,854.2	214.7[t]	5.6	295.8	584.2	26.3
1990	3,589.9	212.5	5.9	310.5	566.5	26.0
Courtaulds (U.K.)						
1993[u]	$2,995.9	$155.9[v]	5.2%	$198.9	$58.9	19.0
1992[u]	3,114.4	227.6	7.3	159.2	58.0	21.0
1991[u]	2,916.8	215.2	7.4	190.7	60.1	22.7
1990[u]	2,870.3	217.0[w]	7.6	na	60.1	23.6
Kemira (Finland)						
1993	$2,073.2	$48.5	2.3%	$148.9	na	11.4
1992	1,960.6	(120.8)[d]	—	160.2	na	12.6
1991	1,899.8	(100.0)[d,x]	—	206.7	na	14.3
1990	1,993.3	29.2[y]	1.5	198.9	na	15.3
Novo Nordisk (Denmark)						
1993	$1,877.0	$220.1	11.7%	$369.1	$269.3	11.6
1992	1,651.1	196.9	11.9	302.0	234.9	10.7
1991	1,444.6	143.2	9.9	208.0	207.9	9.6
1990	1,244.8	120.1	9.6	180.9	184.4	8.7
Laporte (U.K.)						
1993	$1,316.8	$116.5	8.8%	$73.3	$9.8	7.1
1992	783.5	96.1	12.3	111.3	9.2	5.4
1991	924.2	104.5	11.3	81.1	6.6	5.5
1990	974.5	107.5	11.0	61.6	6.3	5.6
Dyno (Norway)						
1993	$1,160.0	$21.3	1.8%	$120.7	$15.2	7.3
1992	1,055.0	7.2	0.7	109.2	14.5	7.5
1991	1,089.4	(8.1)[d]	—	103.6	16.5	7.0
1990	1,000.7	17.5	1.7	121.4	16.8	7.3

Note: All corporate consolidated sales exclude sales of companies owned less than 50%. Monetary statistics for all years are converted from local currency to U.S. dollars on the basis of 1993 conversion factors as follows: $1.00 U.S. = 34.60 Belgian francs, 6.48 Danish crowns, 5.71 Finnish marks, 5.66 French francs, 1.65 German marks, 1,574 Italian lire, 1.86 Netherlands guilders, 7.09 Norwegian crowns, 1.48 Swiss francs, and 0.666 British pounds. **a** Net income as a percentage of sales. **b** Data for 1993 figures exclude results of Zeneca, spun off on June 1, 1993. **c** Excludes nonrecurring loss of $174 million. **d** Net loss. **e** Excludes nonrecurring loss of $399 million. **f** Excludes nonrecurring gain of $138 million. **g** Fiscal year ends Sept. 30. **h** Data for 1993 figures exclude results of Nobel Industries, acquired Nov. 8, 1993. **i** Excludes nonrecurring loss of $77 million. **j** Excludes nonrecurring loss of $36 million. **k** Excludes nonrecurring loss of $60 million. **l** Excludes nonrecurring loss of $34 million. **m** Excludes nonrecurring loss of $85 million. **n** Excludes nonrecurring gain of $53 million. **o** Excludes nonrecurring gain of $52 million. **p** Excludes nonrecurring loss of $55 million. **q** Excludes nonrecurring gain of $155 million. **r** Excludes nonrecurring loss of $31 million. **s** Excludes nonrecurring gain of $26 million. **t** Excludes nonrecurring loss of $48 million. **u** Fiscal year ends March 31. **v** Excludes nonrecurring loss of $33 million. **w** Excludes nonrecurring loss of $104 million. **x** Excludes nonrecurring loss of $16 million. **y** Excludes nonrecurring loss of $32 million.

EAST EUROPEAN PRODUCTION: Chemicals are recovering except in former Soviet states

Millions of lb	1990	1991	1992	1993	% change 1992–93
BELARUS					
Production indexes^a					
All industry	101.6	100.1	91.1	78.3^b	
Chemicals	99.4	94.7	82.4	65.9^b	
Sulfuric acid	2,589	2,196	1,335	867	–36%
Mineral fertilizers^c	13,191	11,350	8,952	5,500	–39
Nitrogen	1,639	1,575	1,461	na	—
Phosphate	563	466	222	na	—
Potassium	10,987	9,308	7,269	na	—
Plastics	1,652	1,577	1,384	1,045^b	–24
Soaps & detergents	86	68	64	55^b	–14
BULGARIA					
Production indexes^a					
All industry	87.4	63.1	49.2	44.6^b	
Chemicals	74.3	52.2	43.1	44.0^b	
Sulfuric acid	1,045	783	759	682^b	–10%
Mineral fertilizers^c	1,296	950	715	649^b	–9
Nitrogen	1,195	869	na	na	—
Phosphate	103	81	na	na	—
Ammonia^d	2,880	2,405	1,364	880^b	–36
Plastics	546	312	275	330^b	20
Ethylene	385	246	220	209	–5
Sodium hydroxide^e	233	169	150	134	–10
Sodium carbonate^f	2,301	1,965	na	na	—
Pesticides^g	22	15	na	na	—
HUNGARY					
Production indexes^a					
All industry	95.5	75.0	67.6	69.2^b	
Chemicals	94.6	77.1	66.6	67.1^b	
Sulfuric acid	537	284	202	161	–21%
Mineral fertilizers^c	1,648	810	444	506	14
Nitrogen	1,034	550	405	486	20
Phosphate	123	29	2	11	500
Potassium	491	231	37	9	–76
Ammonia^d	1,191	703	672	617	–8
Plastics	1,353	1,445	1,522	1,527	0
Polyethylene	486	546	605	570	6
Polypropylene	341	330	326	299	8
Polyvinyl chloride	409	389	389	403	3
Ethylene	515	572	618	607	–2
Propylene	367	387	431	431	0
Sodium hydroxide^e	425	374	306	266	–13
Synthetic detergents	268	196	172	167	–3
Pesticides^g	53	33	29	33	15
POLAND					
Production indexes^a					
All industry	75.8	66.8	69.6	74.7^b	
Chemicals	75.0	64.9	69.3	75.9^b	
Sulfuric acid	3,786	2,394	na	na	—
Mineral fertilizers^c	3,892	3,069	3,282	3,311	1%
Nitrogen	2,864	2,519	2,567	2,693	5
Phosphate	1,027	550	724	618	–15
Ammonia^d	4,325	3,375	3,307	3,527	7
Plastics	1,373	1,305	1,430	1,467	3
Polyethylene	345	330	359	361	1
Polypropylene	189	178	211	240	14
Polystyrene	31	40	53	70	33%
Polyvinyl chloride	447	429	484	464	–4
Ethylene	678	596	na	na	—
Detergents	532	493	427	477	12
Sodium hydroxide^e	889	713	719	651	–9
Methanol	341	224	na	na	—
Synthetic rubber	227	176	196	165	–6
Pesticides^g	44	37	48	48	0
ROMANIA					
Production indexes^a					
All industry	82.2	63.5	49.4	50.1^b	
Chemicals	67.5	50.3	43.2	44.9^b	
Sulfuric acid	2,473	1,639	1,261	1,164	–8%
Mineral fertilizers^c	3,837	2,402	3,082	2,882	–6
Nitrogen	2,695	1,672	na	na	—
Phosphate	935	583	na	na	—
Ammonia^d	4,802	3,031	3,197	3,307	3
Plastics	1,038	768	587	561	–4
Ethylene	535	356	279	268	–4
Sodium hydroxide^e	1,214	1,023	825	717	–13
Sodium carbonate^f	1,406	1,052	1,005	834	–17
Synthetic rubber	224	121	79	66	–17
Synthetic detergents	189	147	106	110	4
Pesticides^g	24	40	37	42	12
RUSSIA					
Production indexes^a					
All industry	100.0	92.1	75.5	63.3	
Chemicals	97.4	91.3	72.1	57.0	
Sulfuric acid	28,087	25,520	21,437	18,040	–16%
Mineral fertilizers^c	35,154	33,092	26,686	18,920	–29
Nitrogen	15,089	14,696	12,793	8,954	–30
Phosphate	10,875	9,405	6,633	4,620	–30
Potassium	8,466	8,989	7,634	5,346	–30
Plastics	7,168	6,519	5,830	4,862	–17
Synthetic detergents	1,927	1,529	1,210	na	—
Sodium hydroxide^e	4,968	4,492	4,180	3,124	–25
Sodium carbonate^f	7,128	6,706	5,940	4,400	–26
Synthetic rubber	na	4,426	3,564	na	—
Pesticides^g	244	191	141	na	—
UKRAINE					
Production indexes^a					
All industry	99.9	95.0	89.3	75.0^b	
Chemicals	99.0	92.1	81.0	60.8^b	
Sulfuric acid	11,024	9,209	6,576	4,400	–33%
Mineral fertilizers^c	10,560	9,240	7,260	5,500	–24
Nitrogen	6,600	6,160	5,588	4,235	–24
Phosphate	3,520	2,860	1,408	1,045	–26
Potassium	220	220	264	220	–17
Ammonia^d	10,811	10,212	10,459	na	—
Plastics	1,817	1,641	1,221	649	–47
Synthetic detergents	662	568	na	na	—
Sodium hydroxide^e	977	975	884	660	–25
Sodium carbonate^f	2,462	2,341	2,400	1,729	–28
Pesticides^g	110	86	48	na	—

a Production indexes developed by C&EN based on information from national statistical offices, 1989 = 100. b Estimated. c Nutrient content basis, as N, P_2O_5, or K_2O. d Nitrogen content. e 96% NaOH. f 98% Na_2CO_3. g On basis of active substance. na = not available. **Sources:** PlanEcon Inc., U.S. Department of Agriculture, national central statistical offices

Foreign Chemical Industries–CANADA

Canadian chemical makers finally put an end to their misfortunes last year. After several years of declining sales and profits, most—though not all—Canadian chemical companies were able to chalk up gains in both sales and profits in 1993. Keys to the improvement were a stronger North American economy and cost-cutting measures undertaken by many chemical companies.

Overall, chemical sales were up 7% and operating profit rose a healthy 22% last year, according to the Canadian Chemical Producers' Association. However, domestic chemical sales advanced only 4%, leaving exports to claim most of the credit for the chemical industry's improved performance. Despite a sluggish global economy that made marketing a tough task, Canadian chemical exports rose 9% to almost $7 billion (in U.S. dollars). Exports, in fact, now account for almost half of Canada's total chemical sales.

But Canada's success at exporting chemicals last year was limited entirely to the U.S., which climbed out of recession much earlier than other major countries throughout the world. Exports to the U.S. rose a hefty 15% to $5.5 billion. That amounts to a lopsided 79% of Canada's chemical exports, compared with only 69% as recently as 1991. Exports to non-U.S. markets were down about 9% last year.

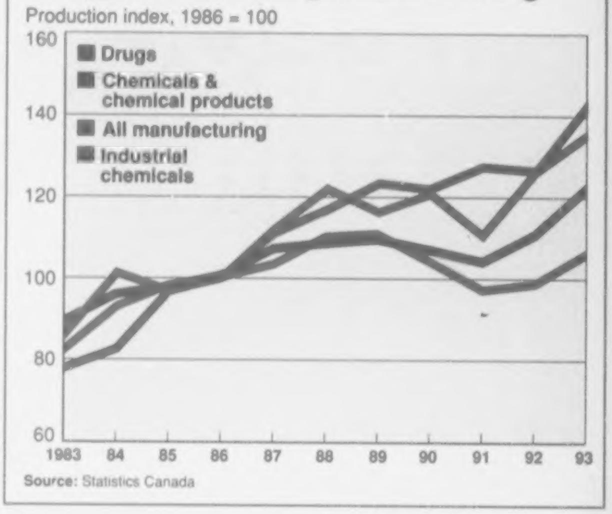
Polyvinyl chloride (PVC) is an excellent example of how important exports are to the Canadian chemical industry. PVC output rose almost 9% last year because exports jumped an astounding 70%. There's little doubt that exports will have to shoulder most of the growth that Canadian chemical producers hope to achieve this year.

COMPANY RESULTS: Sales keep growing

$ Millions (U.S.)	Sales	Net income[a]	Profit margin[b]	Capital expenditures	Employees (thousands)
Celanese Canada					
1993	$376.8	$46.9	12.4%	$16.8	1.6
1992	346.3	28.3	8.2	11.7	1.5
1991	325.0	26.3	8.1	19.2	1.7
1990	254.2	31.9	12.5	18.0	1.8
DuPont Canada					
1993	$1,212.5	$50.7	4.2%	$70.7	4.0
1992	1,093.9	63.2	5.8	83.7	4.1
1991	1,023.4	43.4	4.2	109.7	4.2
1990	1,089.9	48.2	4.4	139.3	4.3
Esso Chemical Canada[c]					
1993	$777.6	$27.0	3.5%	$19.3	1.4
1992	710.4	10.8	1.5	25.5	1.4
1991	670.3	1.5	0.2	20.1	1.4
1990	706.6	18.5	2.6	32.4	1.4
Novacor Chemicals[d]					
1993	$1,782.2	$61.0	3.4%	$202.3	2.9
1992	1,660.2	100.4	6.0	61.0	3.0
1991	1,739.8	22.4	1.3	85.7	3.0
1990	2,545.9	288.0	11.3	166.8	3.3

Note: Monetary statistics for all years are converted from Canadian dollars to U.S. dollars on the basis of the 1993 average exchange rate of $1.00 U.S. = $1.295 Canadian. **a** Excludes extraordinary gains and losses. **b** Net income as a percentage of sales. **c** Now the chemical division of Imperial Oil Ltd. **d** Includes operating income only.

All types of chemical production rising



Source: Statistics Canada

PRODUCTION: More gainers than losers

Thousands of metric tons	1990	1991	1992	1993	% change 1992–93
INORGANIC CHEMICALS					
Aluminum sulfate	204	192	170	217	28%
Ammonia	3,715	3,669	3,770	4,181	11
Ammonium nitrate	1,031	963	1,064	1,025	–4
Carbon black	178	157	161	166	3
Chlorine	1,542	1,402	1,364	1,170	–14
Hydrochloric acid	187	193	168	134	–20
Hydrogen peroxide	na	83	119	128	8
Nitric acid	965	912	960	917	–5
Sodium chlorate	659	695	728	830	14
Sodium hydroxide	1,650	1,498	1,428	1,225	–14
Sulfuric acid	3,311	2,953	3,225	3,683	14
ORGANICS					
Benzene	762	712	686	685	0
Butadiene	192	na	181	174	–4
Ethylene	2,434	2,425	2,521	2,536	1
Formaldehyde	106	114	133	154	16
Methanol	1,884	2,223	2,154	2,253	5
Propylene	765	717	753	766	2
Toluene	425	364	372	337	–9
Urea	2,490	2,397	2,550	3,090	21
Xylenes	514	391	339	311	–8
PLASTICS					
Polyesters, unsaturated	36	33	40	45	12
Polyethylene, high density	364	458	648	652	1
Polyethylene, low density	1,167	1,109	1,041	1,090	5
Polystyrene[a]	215	167	167	158	–5
Polyvinyl chloride	na	287	385	419	9

a Includes acrylonitrile-butadiene-styrene resins. **na** = not available. **Source:** Statistics Canada

SHIPMENTS: Most chemicals perk up as all manufacturing posts gains

$ Millions (U.S.)	1988	1989	1990	1991	1992	1993	% change 1992–93
All manufacturing	$288,549	$296,968	$294,061	$276,592	$280,482	$307,440	10%
Chemicals & chemical products	21,918	22,006	22,331	21,638	21,963	23,007	5
Industrial chemicals, inorganic	2,399	2,433	2,569	2,378	2,419	2,541	5
Industrial chemicals, organic	5,993	5,407	5,169	4,663	4,612	4,570	–1
Plastics & synthetic resins	2,503	2,563	2,819	2,586	2,631	2,789	6
Medicinals & pharmaceuticals	3,111	3,340	3,489	3,770	4,114	4,336	5
Adhesives	207	218	192	180	190	206	8
Paints & varnishes	1,501	1,538	1,618	1,562	1,378	1,429	4
Soaps & cleansers	1,525	1,643	1,518	1,667	1,814	1,843	2
Toilet preparations	1,062	1,126	983	1,048	1,194	1,237	4
Printing ink	256	251	263	238	260	286	10
Synthetic fibers	974	1,023	938	898	960	932	–3
Plastic products	5,416	5,597	5,703	5,341	5,767	6,102	6

Note: Monetary statistics for all years are converted from Canadian dollars to U.S. dollars on the basis of the 1993 average exchange rate of $1.00 U.S. = $1.295 Canadian.
Source: Statistics Canada

CHEMICAL EXPORTS: U.S. share grows

$ Millions (U.S.)	1990	1991	1992	1993
Chemical elements	$ 180	$ 152	$ 154	$ 166
Other inorganic chemicals	1,052	1,026	1,017	1,056
Organic chemicals	1,751	1,528	1,330	1,415
Fertilizers & fertilizer materials	1,432	1,344	1,221	1,261
Synthetic rubber & plastics materials	1,299	1,342	1,378	1,560
Plastics, basic shapes & forms	477	531	594	697
Other chemical products	522	589	709	815
TOTAL	**$6,712**	**$6,512**	**$6,403**	**$6,969**
Exports to U.S.	**$4,631**	**$4,465**	**$4,777**	**$5,487**
U.S. share	**69%**	**69%**	**75%**	**79%**

Note: Converted from Canadian dollars at the following exchange rates: 1990: $1.00 U.S. = $1.160 Canadian; 1991: $1.00 U.S. = $1.156 Canadian; 1992: $1.00 U.S. = $1.271 Canadian; 1993: $1.00 U.S. = $1.295 Canadian. **Source:** Statistics Canada

CHEMICAL IMPORTS: Up for all classes

$ Millions (U.S.)	1990	1991	1992	1993
Inorganic chemicals	$1,128	$1,126	$1,048	$1,192
Organic chemicals	1,788	1,724	1,732	2,028
Fertilizers & fertilizer materials	190	189	182	219
Synthetic & reclaimed rubber	242	221	234	264
Plastic materials	1,311	1,352	1,445	1,746
Plastic film & sheet	436	456	455	519
Other plastic shapes & forms	422	399	426	479
Dyes, except dyeing intermediates	94	88	87	98
Pigments, lakes & toners	115	126	154	202
Paints & related products	252	273	292	360
Other chemical products	1,155	1,211	1,249	1,457
TOTAL	**$7,132**	**$7,166**	**$7,304**	**$8,562**
Imports from U.S.	**$5,366**	**$5,491**	**$5,571**	**$6,571**
U.S. share	**75%**	**77%**	**76%**	**77%**

Note: Converted from Canadian dollars at the following exchange rates: 1990: $1.00 U.S. = $1.160 Canadian; 1991: $1.00 U.S. = $1.156 Canadian; 1992: $1.00 U.S. = $1.271 Canadian; 1993: $1.00 U.S. = $1.295 Canadian. **Source:** Statistics Canada

TRADE BALANCE: Huge jump in surplus . . .

$ Billions (U.S.)	1990	1991	1992	1993	% change 1992–93
Total exports	$122.2	$119.7	$121.0	$136.5	13%
Total imports	117.4	117.0	116.4	130.8	12
Trade balance	4.8	2.7	4.6	5.7	24

. . . and a much higher chemical trade deficit

$ Millions (U.S.)	1990	1991	1992	1993	% change 1992–93
Chemical exports	$6,712	$6,512	$6,403	$6,969	9%
Chemical imports	7,132	7,166	7,304	8,562	17
Chemical trade balance	–420	–654	–901	–1,593	—

Note: Converted from Canadian dollars at the following exchange rates: 1990: $1.00 U.S. = $1.160 Canadian; 1991: $1.00 U.S. = $1.156 Canadian; 1992: $1.00 U.S. = $1.271 Canadian; 1993: $1.00 U.S. = $1.295 Canadian. **Source:** Statistics Canada

PRICES: Rising for most chemicals

Price index, 1986 = 100	1990	1991	1992	1993	% change 1992–93
All commodities	109.7	108.7	109.1	112.7	3%
Chemicals & chemical products	113.8	115.2	113.6	116.4	3
Inorganic industrial chemicals	103.8	103.9	102.7	105.4	3
Sulfuric acid	111.1	110.0	99.5	95.4	–4
Chlorine	93.0	84.9	82.4	86.3	5
Ammonia	78.4	77.2	77.9	85.4	10
Organic industrial chemicals	118.2	120.8	111.7	119.7	7
Benzene-toluene-xylene	127.7	111.4	104.9	97.6	–7
Olefins	133.1	153.0	139.2	153.6	10
Synthetic resins	111.4	102.3	97.7	101.4	4
Polyethylene[a]	115.8	100.0	92.2	90.3	–2
Polystyrene	127.6	114.0	109.9	114.9	5
Thermosets	119.7	115.1	112.3	127.8	14
Synthetic fibers	106.6	105.6	105.7	105.8	0
Agricultural chemicals	106.9	115.0	120.6	121.7	1
Mixed fertilizers	105.2	112.1	107.0	106.2	–1
Pharmaceuticals	125.2	130.6	134.6	136.3	1
Paints & varnish	114.5	119.7	121.4	122.1	1
Soaps & cleansers	116.0	118.0	118.3	118.4	0
Toilet preparations	112.9	116.8	119.5	121.4	2
Pigments, lakes & toners	106.7	107.7	108.2	112.1	4
Inks	103.1	104.4	104.7	105.6	1

[a] Includes both high- and low-density polyethylene. **Source:** Statistics Canada

6 Foreign Chemical Industries–JAPAN

Earlier this year, many of Japan's chemical industry leaders were expecting profits to improve in their 1994 fiscal year, which began April 1. At about the same time last year, they thought exactly the same thing about fiscal 1993. It didn't work out that way.

Chemical sales were down another 6% in fiscal 1993, according to C&EN's survey of 12 of Japan's top chemical companies. That makes 1993 the third successive year in which sales have declined. Worse yet, chemical profits plummeted a whopping 40% to their lowest levels since 1982.

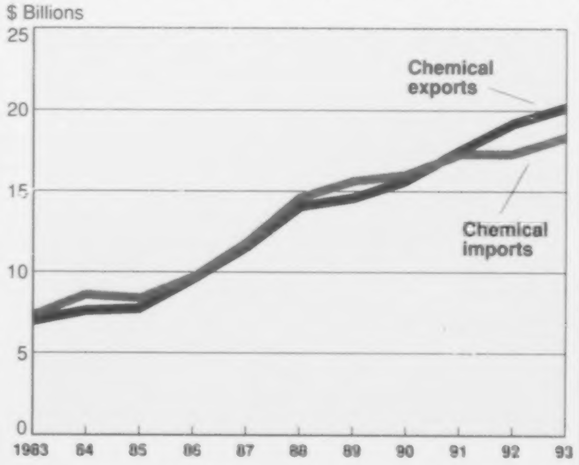
Things may not get much better this year. The Japan Petrochemical Industry Association recently noted that there is "no clear confirmation" that petrochemical markets have hit bottom. Many of those markets, such as cars and home appliances, have shown few signs of recovery. Low demand from its customers is exactly what caused Japan's chemical business to deteriorate last year.

INDUSTRY TRENDS: Weakness in many areas

Production index, 1990 = 100	1990	1991	1992	1993	% change 1992–93
All manufacturing	100.0	102.1	95.8	91.2	–5%
All chemicals	100.0	102.2	102.5	101.7	–1
Inorganic chemicals & pigments	100.0	101.2	96.2	90.9	–6
Alkalies & chlorine	100.0	99.1	97.0	94.2	–3
Organic chemicals	100.0	104.3	105.7	102.0	–4
Petrochemicals	100.0	102.9	104.5	102.0	–2
Aromatics	100.0	107.4	119.3	127.1	6
Cyclic intermediates & dyes	100.0	104.8	105.9	103.5	–2
Plastics	100.0	101.2	99.4	96.4	–3
Synthetic fibers	100.0	100.9	100.5	95.3	–5
Synthetic rubber	100.0	96.0	97.4	91.9	–6
Fertilizer	100.0	97.8	95.5	92.8	–3
Medicinals and drugs	100.0	102.7	102.6	102.8	0

Source: Ministry of International Trade & Industry

Japan's chemical trade balance improves



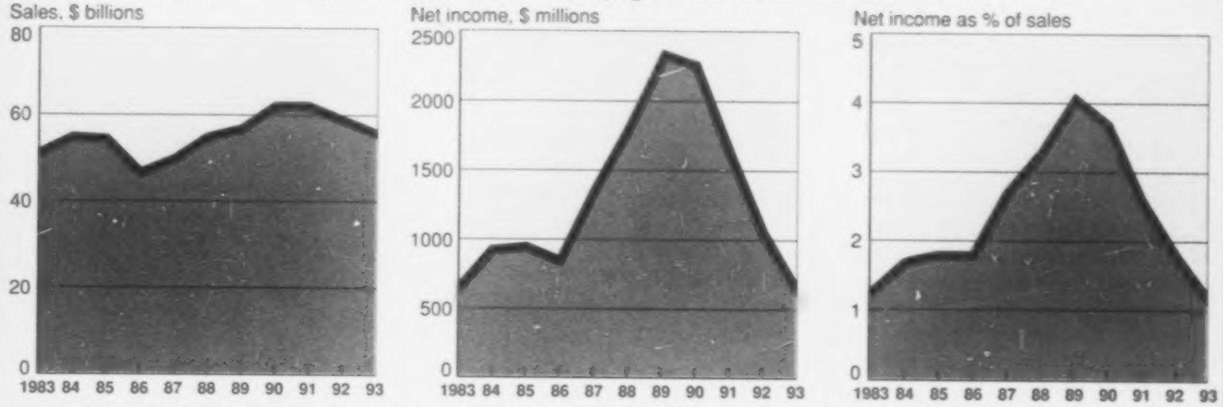
Note: Converted from yen to U.S. dollars on the basis of the average exchange rate for each year. **Source:** Ministry of International Trade & Industry

PRODUCTION: Very few chemicals gain

Thousands of metric tons, unless otherwise indicated	1990	1991	1992	1993	% change 1992–93
INORGANIC CHEMICALS					
Ammonia	1,831	1,855	1,788	1,708	–5%
Ammonium chloride	246	239	233	221	–5
Ammonium sulfate	1,803	1,781	1,830	1,681	–8
Calcium carbide	294	303	270	245	–9
Calcium superphosphate	472	420	396	393	–1
Carbon black	783	793	771	702	–9
Chlorine, liquid	1,042	1,027	978	900	–8
Hydrochloric acid	637	702	706	689	–2
Nitrogen[a]	8,299	8,767	9,129	8,957	–2
Oxygen[a]	8,787	9,000	8,067	7,946	–2
Sodium carbonate	1,135	1,104	1,057	1,056	0
Sodium hydroxide	3,917	3,905	3,866	3,777	–2
Sodium silicate	788	787	722	733	2
Sulfuric acid	6,887	7,057	7,100	6,937	–2
Titanium dioxide	280	279	252	246	–2
ORGANIC CHEMICALS					
Acetaldehyde	384	384	391	350	–11
Acetic acid	462	458	451	484	7
Acetone	334	369	377	350	–7
Acrylonitrile	593	604	621	594	–4
Benzene[b]	2,768	3,050	3,309	3,327	1
Butadiene	827	847	851	809	–5
Butanol	300	334	371	388	5
Caprolactam	509	531	548	510	–7
Cyclohexane	629	584	632	633	0
Dioctyl phthalate	295	305	297	279	–6
Ethylene	5,810	6,142	6,104	5,773	–5
Ethylene dichloride	2,660	2,642	2,708	2,735	1
Ethylene glycol	501	609	560	527	–6
Ethylene oxide	674	760	721	680	–6
Methanol	84	77	34	58	71
Octanol	283	295	327	312	–5
Phenol	403	495	538	513	–5
Phthalic anhydride[b]	161	162	165	152	–8
Propylene	4,215	4,431	4,536	4,272	–6
Propylene glycol	298	301	302	287	–5
Styrene	2,161	2,227	2,182	2,167	–1
Terephthalic acid	1,338	1,434	1,425	1,553	9
Toluene[b]	1,078	1,119	1,150	1,191	4
Toluene diisocyanate	116	136	132	137	4
Urea	776	730	725	725	0
Xylene[b]	2,652	2,918	3,203	3,462	8
PLASTICS					
Phenolic resins	385	383	356	328	–8
Polyethylene	2,888	2,982	2,980	2,762	–7
Polypropylene	1,942	1,963	2,038	1,950	–4
Polystyrene	2,097	2,121	2,005	1,966	–2
Polyvinyl chloride	2,049	2,055	1,981	1,980	0
SYNTHETIC RUBBER	1,426	1,377	1,388	1,310	–6

[a] Millions of cubic meters. [b] Petroleum-based product only.
Source: Ministry of International Trade & Industry

Income and profitability set 10-year lows for Japanese chemical makers



Note: Based on results of 12 leading Japanese chemical companies: Asahi Chemical, Dainippon Ink & Chemicals, Hitachi Chemical, Mitsubishi Kasei, Mitsubishi Petrochemical, Mitsui Toatsu Chemicals, Sekisui Chemical, Showa Denko, Sumitomo Chemical, Takeda Chemical Industries, Teijin, and Toray Industries. The fiscal year for most, but not all, of these companies ends March 31. Monetary statistics for all years converted from yen to U.S. dollars on the basis of the 1993 average exchange rate of $1.00 U.S. = 109.5 yen.
Sources: Toyo Keizai Shinposha, Nihon Keizai Shimbon America

COMPANY RESULTS: Income takes a beating as sales drop for most firms

$ Millions	Net sales	Net income	Profit margin[a]	Total assets	Employees (thousands)
Asahi Chemical Industry[b]					
1993	$8,557	$102.1	1.2%	$ 9,967	17.6
1992	9,084	151.6	1.7	10,077	18.1
1991	8,906	268.1	3.0	9,491	15.5
1990	8,817	353.4	4.0	9,121	15.3
Dainippon Ink & Chemicals[b]					
1993	$4,244	$57.2	1.3%	$6,315	7.3
1992	4,472	64.1	1.4	6,198	7.2
1991	4,727	72.5	1.5	5,910	7.0
1990	4,615	75.8	1.6	5,360	7.2
Hitachi Chemical[b]					
1993	$2,300	$19.5	0.8%	$1,802	5.2
1992	2,560	19.5	0.8	1,942	5.6
1991	2,843	9.7	0.3	2,002	5.8
1990	2,875	37.0	1.3	1,844	5.3
Mitsubishi Kasei[b]					
1993	$6,363	$ 29.2	0.5%	$8,695	11.3
1992	6,485	45.7	0.7	8,697	10.0
1991	6,644	48.8	0.7	9,555	9.3
1990	7,039	169.4	2.4	9,063	9.1
Mitsubishi Petrochemical[b]					
1993	$2,984	$ (42.5)[c]	—	$3,666	4.3
1992	3,400	59.8	1.8%	5,382	3.5
1991	3,716	141.2	3.8	5,732	3.4
1990	3,968	236.2	6.0	5,582	3.3
Mitsui Toatsu Chemicals[b]					
1993	$3,288	$ 2.9	0.1%	$6,035	5.6
1992	3,610	27.6	0.8	5,797	5.7
1991	3,857	65.0	1.7	5,822	5.6
1990	3,989	113.8	2.9	5,689	5.5

$ Millions	Net sales	Net income	Profit margin[a]	Total assets	Employees (thousands)
Sekisui Chemical[b]					
1993	$6,280	$102.3	1.6%	$6,075	6.0
1992	6,162	91.4	1.5	6,110	6.0
1991	5,938	194.2	3.3	5,765	5.8
1990	5,638	238.7	4.2	5,606	5.6
Showa Denko[d]					
1993	$4,227	$(208.2)[c]	—	$6,443	5.3
1992	4,648	(60.3)[c]	—	7,503	5.4
1991	5,269	1.8	0%	7,720	5.4
1990	5,204	103.4	2.0	7,195	5.3
Sumitomo Chemical[d]					
1993	$4,984	$(2.5)[c]	—	$7,774	8.0
1992	5,702	50.9	0.9%	7,778	8.0
1991	6,406	139.2	2.2	8,202	7.9
1990	6,548	151.5	2.3	7,391	7.8
Takeda Chemical Industries[b]					
1993	$5,131	$338.6	6.6%	$7,220	11.2
1992	5,160	288.6	5.6	7,074	11.2
1991	5,124	296.5	5.8	6,787	11.1
1990	5,032	339.0	6.7	6,641	11.0
Teijin[b]					
1993	$2,840	$ 69.4	2.4%	$5,110	7.6
1992	3,033	98.6	3.2	5,781	7.2
1991	3,098	136.0	4.4	5,342	6.8
1990	2,976	18[illegible].5	6.2	5,321	5.7
Toray Industries[b]					
1993	$4,835	$168.6	3.5%	$7,596	10.8
1992	5,300	219.3	4.1	7,587	10.7
1991	5,474	248.2	4.5	7,591	10.4
1990	5,348	264.8	5.0	6,864	10.3

Note: Monetary statistics for all years converted from yen to U.S. dollars on the basis of 1993 average exchange rate of $1.00 = 109.5 yen. **a** Net income as a percentage of sales. **b** Fiscal year ends March 31. **c** Net loss. **d** Fiscal year ends Dec. 31. **Sources:** Toyo Keizai Shinposha, Nihon Keizai Shimbon America

Foreign Chemical Industries–ASIA

Asia features some of the world's fastest developing economies, with China at the forefront. China's gross domestic product soared more than 13% in 1993 and industrial production leaped 21%. Output of some key chemicals rose strongly, with that of sodium carbonate up 16%, synthetic detergents 6%, and man-made fibers 4%. But production of pesticides fell 11%, sulfuric acid 7%, and ammonia 4%. China's chemical exports rose 11%, led by 20% growth in plastics and plastic products, 19% in rubber products, and 10% in organic chemicals.

Taiwan racked up 7% production growth last year both for chemicals and chemical products, far above the 2% rise for all manufacturing. Chemical sectors posting the best output gains were industrial catalysts and additives, 13%, plastics and resins, 10%, and synthetic rubber, 8%. Chemical exports, including plastics and rubber products, were up 6%, led by a 20% rise in inorganic chemicals.

South Korea's gross domestic product soared more than 10% in 1993. Output of chemicals and chemical products also jumped 10%, compared with 4% for all manufacturing. And chemical exports were up 10%.

Meanwhile, India's production of chemicals and chemical products last year rose 5%, with basic chemicals up 12%—compared with 1% growth for all manufacturing.

INDIA

INDUSTRY TRENDS: Basic chemicals soar

Industrial production index, 1981 = 100	1990	1991	1992	1993	% change 1992–93
All manufacturing	190.7	207.8	204.6	206.1	1%
Chemicals & chemical products	247.4	254.3	261.3	274.4	5
Basic chemicals	190.5	203.2	224.3	250.5	12
Fertilizers, pesticides	262.2	276.2	320.3	319.7	0
Drugs, medicines	322.4	305.1	280.2	277.5	–1
Detergents	160.0	164.5	162.3	160.3	–1
Rubber, petroleum, plastic & coal products	173.5	173.4	171.7	177.4	3

Note: Years end March 31. **Source:** Central Statistical Organization, India Ministry of Planning

PRODUCTION: Polymers make big gains

Thousands of metric tons	1990	1991	1992	1993	% change 1992–93
Fertilizer[a]	8,543	9,045	9,863	9,736	–1%
Nitrogen	6,747	6,993	7,301	7,430	2
Phosphate	1,796	2,052	2,562	2,306	–10
Sodium carbonate	1,377	1,385	1,409	1,391[b]	–1
Sodium hydroxide	933	992	1,036	1,079[b]	4
Nylon & polyester filament yarn	189	199	213	278[b]	30
Polyvinyl chloride resins	132	125	151	223[b]	47
Synthetic rubber	53	57	55	47[b]	–15

Note: Years end March 31. **a** Nutrient content basis, as N or P_2O_5. **b** Provisional value.
Sources: Central Statistical Organization, Indian government agencies

CHINA

FOREIGN TRADE: Chemical imports fall

$ Millions	1991	1992	1993	% change 1992–93
Total exports[a]	$71,910	$84,940	$91,763	8%
Total imports[b]	63,791	80,585	103,950	29
Overall trade balance	8,119	4,355	–12,187	–380
Chemical exports[a,c]	na	5,952	6,597	11
Organic chemicals	911	1,403	1,541	10
Inorganic chemicals	913	1,050	1,145	9
Dyeing, tanning, coloring materials	335	354	373	5
Pharmaceuticals[a]	743	460	427	–7
Essential oils, perfumes, cleansing materials	220	181	216	19
Plastics, plastic products	na	1,516	1,825	20
Rubber products	na	313	373	19
Chemical imports[b,c]	na	12,484	11,165	–11
Organic chemicals	1,884	1,876	1,708	–9
Inorganic chemicals	209	378	436	15
Dyeing, tanning, coloring materials	345	500	592	18
Pharmaceuticals	490	319	263	–18
Fertilizers[d]	3,229	3,004	1,479	–51
Plastics, plastic products	na	4,754	4,956	4
Rubber products	na	555	598	8
Chemical trade balance[c]	na	–6,532	–4,568	30

Note: Data supplied in U.S. dollars by the Chinese government. These values are not recalculated to reflect subsequent changes in monetary exchange rates. In many cases, figures for 1991 are not completely comparable with figures for subsequent years because of changes in plastics and rubber categories. These are indicated as na. **a** Free on board. **b** Includes cost, insurance, and freight. **c** Includes chemicals and related products, and plastic and rubber products. **d** Manufactured. **na** = Not available.
Source: General Administration of Customs of the People's Republic of China.

PRODUCTION: Largest volume chemicals dip

Thousands of metric tons	1990	1991	1992	1993	% change 1992–93
Synthetic ammonia	21,290	22,016	22,981	22,035	–4%
Fertilizer[a]	18,797	19,795	20,479	20,160	–2
Nitrogen	14,636	15,101	15,705	15,506	–1
Phosphate	4,114	4,597	4,622	4,652	1
Sulfuric acid[b]	11,969	13,329	14,087	13,140	–7
Sodium carbonate	3,795	3,936	4,550	5,300	16
Sodium hydroxide[b]	3,354	3,541	3,795	3,885	2
Plastics	2,270	2,830	3,308	3,354	1
Man-made fibers	1,654	1,910	2,132	2,215	4
Ethylene	1,572	1,761	2,003	2,040	2
Synthetic detergents	1,514	1,462	1,666	1,765	6
Benzene	562	726	803	832	4
Synthetic rubber	318	336	373	385	3
Pesticides[c]	228	255	281	249	–11

a Nutrient content basis, as N, P_2O_5, or K_2O. **b** 100%. **c** On basis of active substance.
Sources: State Statistical Bureau of the People's Republic of China, China Statistical Information & Consultancy Service Center

PRODUCTION: Petrochemicals, polymers lead strong overall growth

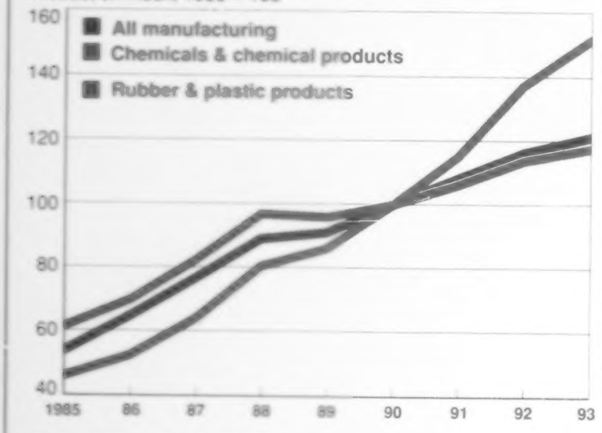
Thousands of metric tons	1990	1991	1992	1993	% change 1992–93
Ethylene	1,054	1,566	2,769	3,273	18%
Composite fertilizers	1,993	1,927	2,188	2,365	8
Propylene	608	855	1,482	1,808	22
Polypropylene	574	770	1,223	1,436	17
Polyethylene, high density	437	612	1,019	1,189	17
Benzene	381	561	964	1,139	18
Polyethylene, low density	404	552	761	853	12
Polystyrene	592	758	754	809	7
Polyvinyl chloride	526	602	726	760	5

Source: Korean National Statistical Office

Thousands of metric tons	1990	1991	1992	1993	% change 1992–93
Vinyl chloride	374	547	667	680	2%
Sodium hydroxide	332	385	524	507	–3
Butadiene	168	205	376	486	29
Acrylonitrile-butadiene-styrene	204	227	310	350	13
Synthetic detergents	342	363	360	339	–6
Carbon black	216	232	248	300	21
Paint	276	305	330	289	–12
Acrylonitrile	87	80	104	124	19

South Korea's growing overall economy supports booming chemical industry

Production index, 1990 = 100



Source: Korean National Statistical Office

FOREIGN TRADE: Chemical exports grow

$ Millions	1991	1992	1993	% change 1992–93
Exports[a]	$71,870	$76,632	$82,236	7%
Imports[b]	81,525	81,775	83,800	2
Trade balance	–9,655	–5,143	–1,564	70
Chemical exports[a,c]	3,191	4,455	4,922	10
Chemical elements & compounds	1,072	1,505	1,639	9
Chemical fertilizers	168	184	197	7
Chemical imports[b,c]	8,269	7,668	8,235	7
Organic chemicals	3,467	2,814	2,919	4
Plastics	1,382	1,356	1,516	12
Inorganic chemicals	782	786	870	11
Medicinal products	353	408	470	15
Chemical trade balance	–5,098	–3,213	–3,313	–3

Note: Data supplied in U.S. dollars by the South Korean government. These values are not recalculated to reflect subsequent changes in monetary exchange rates. **a** Free on board. **b** Includes cost, insurance, and freight. **c** Includes chemicals and related products.
Source: Korean Office of Customs Administration

INDUSTRY TRENDS: Chemicals do well

Index, 1990 = 100	1990	1991	1992	1993	% change 1992–93
Chemicals and chemical products					
Production	100.0	116.3	138.0	152.1	10%
Shipments	100.0	114.2	134.1	148.9	11
Inventories	100.0	145.8	181.7	203.5	12
Rubber and plastic products					
Production	100.0	108.3	114.8	119.9	4
Shipments	100.0	106.9	112.2	118.3	5
Inventories	100.0	121.5	125.2	132.7	6
All manufacturing					
Production	100.0	109.7	116.2	121.1	4
Shipments	100.0	109.8	116.6	122.9	5
Inventories	100.0	121.1	129.8	132.8	2

Source: Korean National Statistical Office

PRICES: Falling for chemicals, plastics

Producer price index, 1990 = 100	1990	1991	1992	1993	% change 1992–93
All commodities	100.0	104.7	107.0	108.6	1%
Chemical products	100.0	103.8	102.0	101.0	–1
Basic chemicals	100.0	100.5	94.9	91.2	–4
Synthetic rubber & plastic materials	100.0	106.0	94.4	90.0	–5
Chemical fibers	100.0	105.2	103.3	100.1	–3
Drugs, pharmaceuticals	100.0	101.1	104.0	104.5	0
Soaps, detergents & toiletries	100.0	103.5	106.7	111.3	4
Other chemical products	100.0	107.3	111.3	112.2	1
Rubber & plastic products	100.0	102.8	101.2	101.4	0
Rubber products	100.0	101.4	103.4	104.3	1
Plastic products	100.0	103.3	100.6	100.6	0

Source: Korean National Statistical Office

TAIWAN

INDUSTRY TRENDS: Chemicals and chemical products outperform all manufacturing

Industrial production index, 1991 = 100	1990	1991	1992	1993	% change 1992–93
All manufacturing	93.0	100.0	104.1	106.5	2%
Chemicals	88.7	100.0	114.0	121.8	7
Basic chemicals	95.0	100.0	112.5	118.5	5
Petrochemicals	90.2	100.0	112.8	120.9	7
Fertilizers	98.1	100.0	102.0	100.5	–1
Synthetic fibers	89.1	100.0	112.4	117.2	4
Plastics & resins	83.9	100.0	119.1	131.0	10
Synthetic rubber	90.4	100.0	102.0	110.3	8

Industrial production index, 1991 = 100	1990	1991	1992	1993	% change 1992–93
Chemical products	93.3	100.0	108.4	115.6	7%
Paints & varnishes	94.7	100.0	113.2	124.9	10
Drugs & medicines	98.4	100.0	105.9	106.2	0
Pesticides	101.8	100.0	102.3	100.4	–2
Industrial catalysts & additives	85.0	100.0	109.4	124.0	13
Rubber products	96.2	100.0	103.2	93.4	–10
Plastic products	98.1	100.0	96.0	90.8	–5

Source: Taiwan Ministry of Economic Affairs

FOREIGN TRADE: Chemical deficit rising

$ Millions	1991	1992	1993	% change 1992–93
Exports[a]	$76,178	$81,470	$84,935	4%
Imports[b]	62,861	72,007	77,061	7
Trade balance	13,317	9,463	7,874	–17
Chemical exports[a,c]	6,741	7,224	7,629	6
Organic chemicals	440	472	501	6
Inorganic chemicals	146	149	179	20
Dyeing, tanning, coloring materials	342	409	463	13
Pharmaceuticals	41	48	41	–16
Essential oils, perfumes, cleansing materials	161	158	170	8
Plastics, plastic products	4,581	4,815	5,011	4
Rubber products	590	640	682	7
Chemical imports[b,c]	9,339	9,565	10,156	6
Organic chemicals	3,654	3,599	3,801	6
Inorganic chemicals	746	754	708	–6
Dyeing, tanning, coloring materials	631	690	724	5
Pharmaceuticals	226	298	332	11
Essential oils, perfumes, cleansing materials	186	287	309	8
Plastics, plastic products	1,752	1,877	2,008	7
Rubber products	459	540	583	8
Chemical trade balance	–2,598	–2,341	–2,527	–8

Note: Data supplied in U.S. dollars by the Taiwan government. These values are not recalculated to reflect subsequent changes in monetary exchange rates. **a** Free on board. **b** Includes cost, insurance, and freight. **c** Includes chemicals and related products, and plastic and rubber products. **Source:** Taiwan Ministry of Finance

PRODUCTION: Up for most chemicals

Thousands of metric tons, unless otherwise noted	1990	1991	1992	1993	% change 1992–93
Polyester[a]	1,290	1,457	1,641	1,753	7%
Terephthalic acid[b]	798	1,005	1,302	1,635	26
Polyvinyl chloride	921	978	1,043	1,078	3
Vinyl chloride	665	595	650	780	20
Ethylene	776	709	734	742	1
Sulfuric acid	751	776	715	644	–10
Acrylonitrile-butadiene-styrene	384	472	569	642	13
Polystyrene	288	476	522	587	12
Paints	312	322	379	419	11
Propylene	398	389	401	418	4
Oxygen[c]	370	364	377	376	0
Ammonium sulfate	509	478	445	370	–17
Polyethylene[d]	360	334	360	369	2
Styrene	355	368	338	369	9
Hydrochloric acid	257	291	329	339	3
Calcium superphosphate	338	346	332	335	1
Benzene	249	234	267	276	4
Ammonia, anhydrous	263	296	272	267	–2
Urea	229	206	221	236	7
Dioctyl phthalate	188	192	225	210	–7
Hydrogen[c]	71	86	57	110	94
Phthalic anhydride	80	70	107	106	–1
Methyl methacrylate	3	30	56	76	37

a Filament and staple. **b** Pure terephthalic acid. **c** Millions of cubic meters. **d** Low and high density. **Source:** Taiwan Ministry of Economic Affairs

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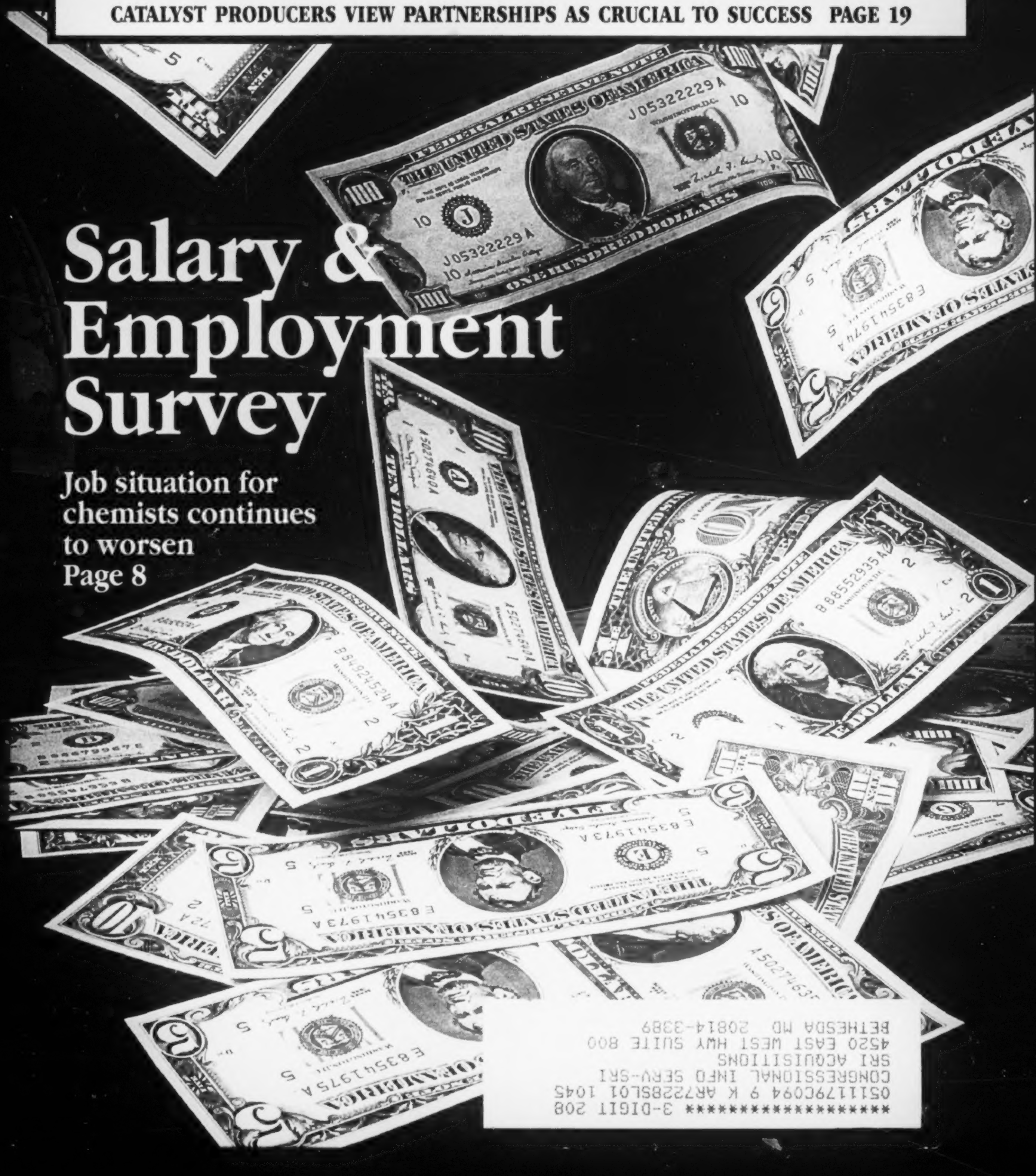
CATALYST PRODUCERS VIEW PARTNERSHIPS AS CRUCIAL TO SUCCESS PAGE 19



Salary & Employment Survey

Job situation for chemists continues to worsen
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CHEMICAL & ENGINEERING NEWS
C&EN
JULY 11, 1994

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- EPA mandate that 30% of oxygenates used in reformulated gasoline must come from renewable sources fuels heated debate. Page 4
- Panel of Michigan scientists finds insufficient evidence to phase out chlorine and chlorine-containing compounds as industrial feedstocks as proposed by a U.S.-Canadian group. Page 5
- Elevated levels of organolead compounds in vintage French wine indicate the history of leaded gasoline use over the past 40 years. Page 5
- New uses for catalytic antibodies in organic synthesis include peptide bond formation and thermodynamically disfavored eliminations. Page 6
- Insulation manufacturers object to the National Toxicology Program's identification of fiberglass as a possible carcinogen based solely on laboratory animal studies. Page 6
- New conflict-of-interest policies at NIH and NSF require grant recipients to disclose significant financial interests to their respective institutions. Page 7

COVER: Photo by Henryk T. Kaiser/Uniphoto Picture Agency

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Catalyst industry sees partnerships with customers and end users as means of survival and success in a sector pressured into change and growth by regulation. **Page 19**

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Chemists' salaries show a 4.7% gain, down from last year's gain of 5.2%, and unemployment, at a 20-year peak of 2.7%, continues to grow for the fifth consecutive year. Page 8

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Editor: Michael Heylin (202) 872-4501
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Assistant Managing Editors: Ernest L. Carpenter, James H. Krieger, Janice R. Long, Rebecca L. Rawls, William J. Storck
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LETTERS

Plutonium vitrification

Congratulations to C&EN and Bette Hileman for the excellent article on plutonium (C&EN, June 13, page 12). The history and primary issues were reported thoroughly and clearly. I hope the article elevates the level and quality of debate on the subject. To that end, I have a few comments, which are my own, and do not necessarily represent the views of the Department of Energy or the Westinghouse Savannah River Co., for whom I am a senior advisory scientist.

The most urgent need, as the article pointed out, is to stabilize and secure the surplus plutonium in Russia, including plutonium from dismantled weapons and other forms of plutonium. To achieve that, it appears three things will be required. First, the U.S. must take similar action, although theft and diversion are less likely in the U.S. Second, the plutonium must be put in a form that is chemically stable and monitorable (accountable), and then secured via an internationally approved program of security, accountability, and inspection. Since permanent disposal is not acceptable to Russia (nor to most other nations), their storage form must permit recovery for plutonium for subsequent use as fuel. Third, the storage form should be such that it would take the host country a number of months to produce a weapon from the plutonium, thus giving the international community time to react.

Stabilizing surplus plutonium as borosilicate glass (without added fission products) may be the fastest and surest way to achieve these objectives. This form of plutonium, under an approved International Atomic Energy Agency or bilateral safeguards program (guards, fences, intrusion detectors, accountability, and inspections), would give a very high level of assurance that the plutonium could not be diverted quickly to weapons. This case was presented in the Westinghouse Savannah River Report ("Vitrification of Excess Plutonium," Westinghouse Savannah River Co., WSRC-RP-93-775, May 1993, Savannah River Site, Aiken, S.C.) on vitrification options that was input to the National Academy of Sciences (NAS) study and report ("Management and Disposition of Excess Weapons Plutonium," National Academy of Sciences, National Academy Press, Washington, D.C., 1994).

Several unresolved technical issues with plutonium vitrification were identified in the article; however, these are normal process development items, not "showstoppers."

The article noted that the fuel value of plutonium is a central issue with wide disagreement. These disagreements exist, in part, because of the great complexity of analyzing the net cost and benefit of using plutonium as fuel. These analyses necessarily include many undefined variables and assumptions that require subjective judgments. However, it is important to note that nearly all the world's nations that have a modern nuclear power industry expect to use plutonium eventually in some kind of power-generating reactor. Indeed, essentially all experts agree that, eventually, plutonium will be a cost-competitive fuel for production of electricity. The disagreements are on when that time will come. The Japanese, French, and Russians (and perhaps others) believe that that time is imminent.

Unfortunately, objective debate is clouded by those who believe that all plutonium should be banished from Earth, regardless of its potential value as an energy source, because of its possible use in nuclear weapons. It is quite clear that the cornerstone of the world's nuclear nonproliferation program will be international control of and accountability for the very large and growing inventory of fissile material that is being beneficially used to produce much-needed clean energy throughout the world. It is not beneficial to this very important nonproliferation effort for any one nation to unilaterally refrain from producing, and beneficially using, this resource.

The two principal recommendations in the NAS report are long-term options requiring major capital projects. Some aspects of each of those approaches are in dispute among nuclear experts. It may not be possible to put such material in a geologic repository because of criticality safety concerns and international safeguard requirements. Even if it were possible, it may not be wise because it would waste a future, clean, valuable energy source that would enhance U.S. efforts toward greater energy independence, and it would create a convenient plutonium mine when the fission products decayed to low levels, thus requiring international safeguards of the repository in perpetuity.

There are also some issues with the oth-

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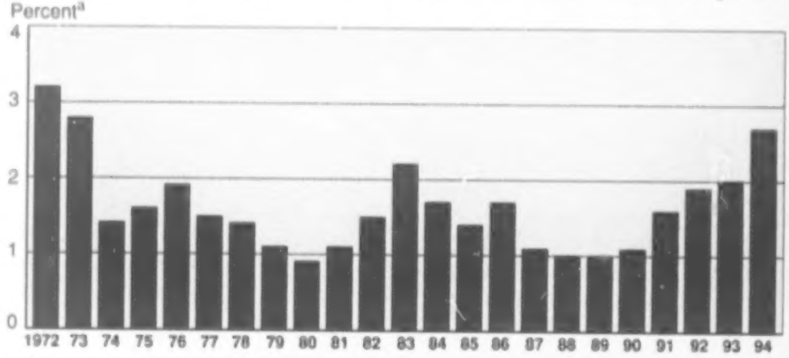
Job Market For Chemists Weakest In More Than 20 Years, Salary Gains Dip

Annual ACS survey of members shows a further big surge in the growth in unemployment that has been under way since 1990

Michael Heylin, C&EN Washington

Joblessness among chemists highest in more than 20 years



a Unemployed, but seeking employment, as of March 1 each year. **Source:** ACS survey

It is hard to find many positive signs in the masses of data collected for the American Chemical Society's latest annual employment and salary survey of its members.

Survey results indicate that the employment situation is the worst it has been since the early 1970s, a notoriously bad time for the chemical community. Year-to-year gains in basic salaries are down. And bonuses and other additional professional income are actually smaller than they were last year.

Unemployment among chemists is at 2.7%, up from 2.0% one year earlier and from 1.1% as recently as 1990. Individual chemists' salaries show a mean 12-month gain of 4.7%. This shows slippage from the mean 5.2% gain posted the previous year.

As in recent years, the survey was directed by statistician and senior research analyst Joan S. Burrelli of ACS's Office of Professional Services.

Younger chemists post largest salary gains

Mean salary increase[a]	By degree B.S.	 M.S.	 Ph.D.
BY EMPLOYMENT			
Industry	5.3%	5.1%	4.6%
Government	4.1	4.4	4.2
Academia	4.8	3.4	4.2
TOTAL	5.2%	4.9%	4.5%
BY AGE			
20–29	6.8%	6.2%	4.9%
30–39	6.0	5.9	5.5
40–49	4.2	5.0	4.6
50–59	3.6	4.0	3.8
60–69	4.2	2.9	2.9
TOTAL	5.2%	4.9%	4.5%

a Mean salary increase for individual chemists between March 1, 1993, and March 1, 1994.
Source: ACS survey

The data indicate that much of the softness in both employment and pay is found in industry. Terminations, early retirements, and golden-handshake separations are still thinning the ranks of chemists working in industry, especially older ones. And the little hiring that is being done is apparently mostly of younger, lower paid replacements.

Chemists' unemployment apparently mainly due to cutbacks by industry

	Employed[a] Full time	 Part time	 Postdoc	 Seeking employment
EMPLOYER				
Industry	95.3%	1.3%	0.4%	3.1%
Academia	86.1	3.5	9.0	1.5
Government	92.6	1.5	5.2	0.8
Other nonacademic	78.3	14.1	2.3	5.3
MOST RECENT WORK				
Production	95.3	0.9	0.0	3.8
R&D management	96.4	1.1	0.0	2.6
General management	95.7	2.1	0.0	2.1
Marketing	93.6	2.3	0.0	4.1
R&D	89.6	1.2	7.0	2.2

Note: Some totals do not add to 100.0% because of rounding. a As of March 1, 1994. **Source:** ACS survey

The survey is based on 9,788 responses to questionnaires mailed to 20,000 ACS members. Those polled all live in the U.S. and are not more than 70 years old. They are neither students nor retirees. The data gathered are as of March 1, as they are for previous surveys. About 1,000 of the responses this year are from chemical engineers and others who do not have chemistry as their highest degree. Virtually all the employment and salary data presented in this article are for chemists only.

Total of chemists unemployed, on postdocs, or with part-time jobs at unusually high level

	Chemists								
		By sex		By highest degree			By minority status		
Employment status[a]	Total	Men	Women	B.S.	M.S.	Ph.D.	Minority[b]	Nonminority	Chemical engineers
Employed full time	90.1%	90.5%	88.3%	91.5%	90.7%	89.3%	85.9%	90.7%	91.7%
Employed part time	2.5	2.0	4.3	2.5	3.4	2.2	1.4	2.6	2.3
Postdoctoral or fellowship	2.9	3.1	2.2	0.2	0.3	4.7	7.8	2.1	0.4
Unemployed									
Seeking employment	2.6	2.6	2.6	3.0	3.0	2.3	3.6	2.5	3.1
Not seeking employment	2.0	1.8	2.5	2.8	2.5	1.5	1.3	2.0	2.5

Note: Some totals do not add because of rounding. **a** As of March 1, 1994. **b** Black, Spanish/Hispanic, Native American, Alaskan native, Asian, Pacific Islander, or other. **Source:** ACS survey

Percentage of chemists employed full time dips for the sixth year in a row

Employment status[a]	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
Employed full time	93.7%	95.2%	94.8%	95.4%	95.4%	95.3%	95.2%	94.0%	93.4%	92.8%	91.9%
Employed part time	1.7	1.5	1.5	1.5	1.6	1.5	1.4	1.8	2.2	2.2	2.5
Postdoctoral or fellowship	2.9	1.9	2.0	2.0	2.0	2.2	2.2	2.6	2.4	3.0	2.9
Unemployed	1.7	1.4	1.7	1.1	1.0	1.0	1.1	1.6	1.9	2.0	2.7

Note: Some totals do not add because of rounding. **a** As of March 1, 1994; excludes chemists who are not employed but not seeking employment. **Source:** ACS survey

Of all respondents, 23.9% have a B.S. as their highest degree, 18.7% an M.S., and 57.4% a Ph.D. By gender, 19.6% are women. By race, 86.3% are white, 8.9% Asian, 1.9% Hispanic, 1.6% black, 0.5% American Indian, and 0.8% "other." By place of employment, 62.8% work for industry, 22.6% are in academia, 7.7% work for governments, and 7.0% are employed elsewhere.

The 2.7% unemployment rate from the new survey is the percentage of chemists in the labor force who were jobless, but seeking employment, as of March 1. An additional 2.0% of those who responded to the survey indicated they were unemployed but not seeking employment.

This basic measure of joblessness among chemists in the labor force fluctuates within a relatively narrow range. But it is an extremely sensitive indicator of the employment status of the chemical profession.

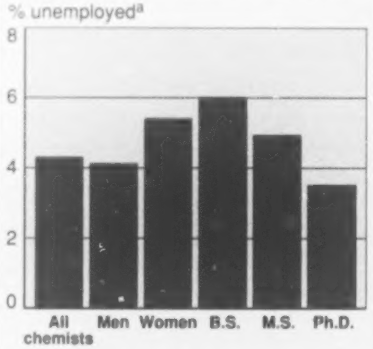
Results from the ACS surveys over the years indicate that in good times for the chemical industry and profession—such as 1979 through 1981 and 1987 through 1990—the number of chemists unemployed but seeking employment hovers very close to 1.0%. If it moves up toward 2.0%, as it did in 1992 and 1993, it indicates a sharply weakening job market, with reduced employment opportunities for younger chemists and decreased job security for those with jobs, especially in the industrial sector.

This year's figure of 2.7% reflects clearly today's especially tough employment situation. It well exceeds the recent high of 2.2% in 1983. At the height of the economic troubles of the early 1970s, this measure of joblessness among chemists peaked at 3.2% in 1972.

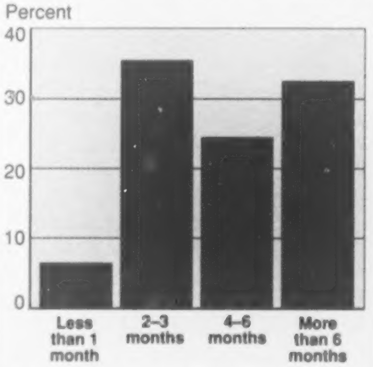
A broader indicator of the job situation for chemists is the sum of those out of work but looking for it, those on postdocs, and those employed part time. In good times this total is about 4.5%, with 1% unemployed, 2% on postdocs, and 1.5% employed part time. In 1993, this total moved up to 7.2%. This year, it is at 8.1%. This is by far the highest on record, with 2.7% unemployed, 2.9% on postdocs, and 2.5% employed part time. In 1983, this total was 6.5%. Exactly comparable figures are not available for 1972; in those days, the analysis of employment was done a little differently and included a "subprofessionally employed" category.

The poor employment situation for chemists permeates all segments of the work force. Doctoral chemists are slightly less likely to be actually unemployed. However, last year they were also less likely to be employed full time, as an unusually high 4.8% of them were in postdoc positions. By gender, more women, 4.4%, were employed part time last year. This com-

Over 4% of chemists were jobless sometime in 1993...

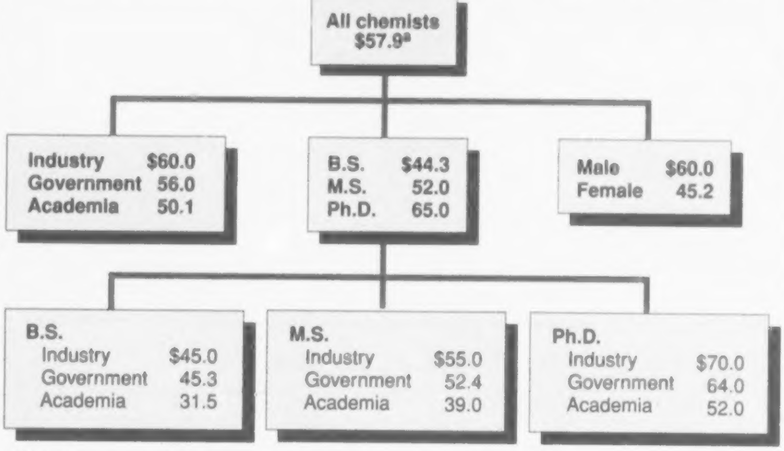


...with a third of these out for six months or more



a Unemployed at sometime in 1993.
Source: ACS survey

Industry salary advantage is greatest for Ph.D. chemists



a Median base annual salaries in thousands of dollars as of March 1, 1994. **Source:** ACS survey

pares with 2.1% for men. This difference, however, is usual. Minority chemists are the least likely to be employed full time. But a high percentage of them, 7.9%, are postdocs. By age, chemists between 50 and 59 are the most likely to be jobless but looking for work. Of respondents to the last survey, 3.5% of them were in this position.

Another indicator of the weak job market is the number of chemists, 4.3%, who were unemployed at some time during 1993. For 1992 the corresponding number was 4.0%. By degree, the 1993 rate ranges from 6.0% for B.S. chemists to 3.5% for Ph.D.s. Of those unemployed during last year, almost one third were jobless for more than six months. This is up from one fourth a year earlier.

The role of industry in the high unem-

Median salaries for bachelor and master chemists showed only weak gains in 1993

$ Thousands	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	% annual change 1993–94	1989–94	1984–94
CHEMISTS' MEDIAN SALARIES[a]														
B.S.	$30.9	$32.0	$33.0	$33.5	$35.4	$37.0	$39.0	$40.3	$42.0	$43.5	$44.3	1.8%	3.7%	3.7%
M.S.	34.0	36.0	37.9	39.0	41.0	43.0	45.0	47.4	50.0	51.5	52.0	1.0	3.9	4.3
Ph.D.	42.0	44.0	47.8	47.7	50.0	52.5	55.0	58.0	60.0	62.8	65.0	3.5	4.4	4.5
All chemists	38.0	40.0	42.5	42.5	45.0	47.3	49.8	52.0	54.6	56.0	57.9	3.4	4.1	4.3

a Base annual salary of chemists employed full time as of March 1, 1994. **Source:** ACS survey

Top 10% of older industrial Ph.D. chemists earn $100,000 or more, lowest 10%, $60,000

Median salary, $ thousands[a]	Years since B.S. degree 2 to 4	5 to 9	10 to 14	15 to 19	20 to 24	25 to 29	30 to 34	35 to 39	40 or more	Overall
INDUSTRIAL CHEMISTS										
B.S.										
90%	$41.0	$50.0	$60.0	$70.0	$ 85.0	$ 80.0	$ 95.0	$ 97.5	—	$ 72.0
75%	36.0	44.5	52.0	60.2	70.0	70.5	80.4	75.0	—	58.0
50%	31.5	39.0	45.0	51.0	58.0	59.6	64.6	65.2	—	45.0
25%	27.8	33.0	39.0	42.8	49.0	50.0	50.0	50.8	—	35.7
10%	23.2	28.5	33.0	36.0	40.8	39.8	41.0	37.5	—	29.2
M.S.										
90%	—	55.0	68.0	76.0	80.5	84.7	104.8	100.0	—	80.7
75%	—	48.0	56.0	65.0	67.0	74.0	88.0	85.0	—	67.0
50%	—	43.0	49.0	55.7	59.7	63.3	68.0	66.3	—	55.0
25%	—	37 7	43.0	48.0	50.0	51.0	56.1	56.7	—	46.0
10%	—	33.0	38.6	42.5	42.0	43.1	49.5	47.4	—	39.0
Ph.D.										
90%	—	63.0	72.0	89.0	100.0	113.0	130.0	118.0	135.0	104.6
75%	—	60.0	65.0	77.9	88.0	96.4	105.0	100.3	109.3	85.2
50%	—	55.0	60.0	68.1	74.0	80.2	85.0	85.6	88.0	70.0
25%	—	52.0	55.0	61.0	66.0	69.3	73.1	71.5	73.0	60.0
10%	—	45.0	50.0	54.0	57.6	59.6	61.0	60.0	57.1	52.5

How to read this table: Using, as an example, industrial B.S. chemists two to four years after they have received their B.S. degree, 90% of these chemists have annual base salaries of $41,000 or less; 75% have annual base salaries of $36,000 or less, 50% have annual base salaries of $31,500 or less, 25% have annual base salaries of $27,800 or less, and 10% have annual base slaries of $23,200 or less, as of March 1, 1994. **Note:** Where no salary data are shown, sample is too small to provide meaningful figure. a As of March 1, 1994. **Source:** ACS survey

Women's salaries about 10% below men's, even after length of service adjustment

Mean salary, $ thousands[a]	B.S.				M.S.				Ph.D.			
	All chemists	Men	Women	Women as % of men	All chemists	Men	Women	Women as % of men	All chemists	Men	Women	Women as % of men
EMPLOYER												
Industry	$49.3	$52.3	$46.6	89%	$58.5	$60.6	$54.6	90%	$75.9	$77.6	$66.3	85%
Academia	32.3	34.4	30.9	90	41.7	44.3	39.5	89	56.7	58.9	51.0	87
Government	46.1	47.5	47.1	99	52.9	54.3	52.2	96	64.9	65.7	61.1	93

a As of March 1, 1994; to facilitate comparison, women's salaries are adjusted for the difference in average length of experience between women and men. **Source:** ACS survey

ployment figures is reflected in data on the last place of employment of those without jobs. In the latest survey, 3.1% of those last employed by industry were jobless but seeking employment. This compares with 1.5% for academia and 0.8% for government. In the previous survey, this gap was not as wide, with 1.9% for industry, 1.6% for academia, and 1.5% for government.

The data in the latest survey on salaries are less bleak than those on employment. At least, there are some gains. (All salary data represent the base salaries of the principal job of chemists. Overtime, bonuses, fees from consulting, and other professionally related income are not included. These are analyzed separately.)

The median salary of all chemists responding to this year's survey is $57,900, up 3.4% up from the year-earlier median of $56,000. The median salary of a group is that which is equaled or exceeded by one half of the sample. This 3.4% growth compares with an average annual gain of 4.1% for the previous five years.

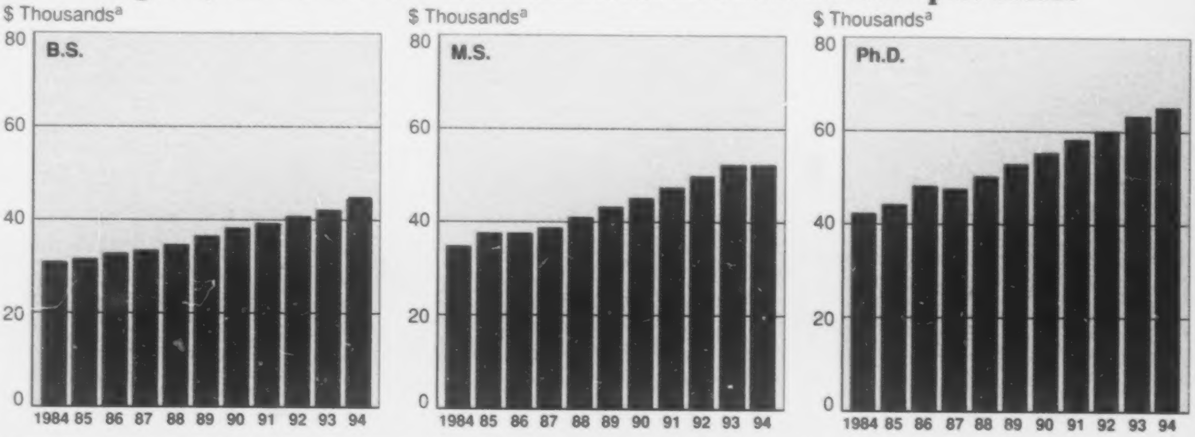
For the academic chemical work force as a group, the gain in salaries in

Keys to higher industry salaries: Get a Ph.D., be a manager, stay a long time

Median salary, $ thousands[a]		Years since B.S. degree									
		2 to 4	5 to 9	10 to 14	15 to 19	20 to 24	25 to 29	30 to 34	35 to 39	40 or more	Overall
CHEMISTS EMPLOYED FULL TIME IN INDUSTRY											
Total											
B.S.		$31.5	$39.0	$45.0	$51.0	$58.0	$59.6	$ 64.6	$65.2	$ 68.0	$45.0
M.S.		—	43.0	49.0	55.7	59.7	63.3	68.0	66.3	62.0	55.0
Ph.D.		—	55.0	60.0	68.1	74.0	80.2	85.0	85.6	88.0	70.0
Sex											
Men	B.S.	31.5	40.0	45.9	52.0	58.9	60.0	66.8	67.2	69.3	48.6
	M.S.	—	43.0	49.0	55.7	60.0	65.0	72.2	68.0	64.5	56.8
	Ph.D	—	55.0	60.5	68.4	75.0	81.6	87.4	86.0	91.0	72.0
Women	B.S.	30.8	36.2	43.1	48.8	50.0	51.6	—	—	—	39.0
	M.S.	—	42.6	49.0	55.0	58.0	51.4	60.5	—	—	48.0
	Ph.D.	—	57.0	58.0	67.0	70.0	70.0	69.5	—	—	60.0
Work function											
General management	B.S.	—	46.0	42.7	55.5	61.4	—	66.0	—	—	52.9
	M.S.	—	—	—	59.0	66.5	—	—	—	—	68.6
	Ph.D.	—	—	—	—	84.0	84.3	113.5	—	—	85.3
R&D management	B.S.	—	46.5	—	—	78.0	—	85.0	—	—	63.0
	M.S.	—	—	—	72.0	64.7	70.0	78.7	85.8	—	70.5
	Ph.D.	—	—	65.4	79.0	88.0	93.4	100.3	95.0	109.3	88.0
Basic research	B.S.	32.6	39.0	44.8	—	—	—	—	—	—	41.0
	M.S.	—	41.0	49.4	—	—	—	—	—	—	49.8
	Ph.D	—	55.6	62.0	70.0	74.5	76.9	84.0	—	—	68.4
Applied research	B.S.	34.0	39.0	45.0	51.0	53.1	59.0	66.8	—	—	43.2
	M.S.	—	43.9	49.0	54.7	60.0	59.3	70.4	61.0	—	54.0
	Ph.D.	—	55.0	59.0	65.0	70.0	75.0	75.0	76.6	82.0	65.0
Production	B.S.	31.5	35.0	42.5	49.0	52.0	—	—	—	—	42.0
	M.S.	—	44.0	43.5	51.2	50.0	56.8	—	—	—	49.4
	Ph.D.	—	—	—	67.0	67.0	73.0	—	—	—	64.9
Marketing	B.S.	32.2	41.0	51.0	58.8	55.0	—	—	—	—	50.4
	M.S.	—	—	—	61.0	—	—	—	—	—	58.0
	Ph.D.	—	—	—	—	—	84.3	—	—	—	75.0

Note: Where no salary data are shown, sample is too small (less than 15) to provide meaningful figure. a As of March 1, 1994. **Source:** ACS survey

For all degrees, salaries for B.S. chemists have risen at slowest rate in past decade



Note: Average salary increases for individual chemists have been larger because of increasing experience. **a** Median base annual salary for chemists employed full time as of March 1 of each year. **Source:** ACS survey

the new survey is 1.6%; for those in government, it is 3.7%. However, for chemists in industry as a group there was no change. In both years, this median salary was $60,000.

Interpreting the differences in median salaries obtained from two surveys carried out one year apart has to be done with care, however. For instance, although the median salary for the entire sample of chemists employed in industry didn't change from the 1993 survey to the one in 1994, the medians for each of the major subgroups—those with B.S. degrees, with M.S. degrees, and with Ph.D.s—all rose. For the B.S. group, the gain was a mere 0.5%, for M.S. chemists it was 1.9%, and for Ph.D.s it was 1.6%. Analyst Burrelli explains that this sort of thing can happen when medians from different studies are compared.

In general, movements in the median salaries of large groups of employees reflect not only the actual changes in the salaries of individuals but also significant changes in the makeup of the population being analyzed. And there is no doubt that the work force of chemists in industry, as a group, is tending to become younger and lower paid.

The results of this year's survey reflect this trend. When asked to report their salaries as of both March 1, 1993, and March 1, 1994, industrial chemists employed on both these dates report a mean gain of 4.9%. This suggests that the lack of growth in the median salary for industrial chemists as a group over the past year is due primarily to a lowering of the experience level of this population with the separation of many older, better paid employees and the hiring of fewer and less experienced replacements.

ACS has been collecting data on the year-to-year salary increases of individual chemists for only two years. Both years show a similar pattern. The bigger percentage gains tend to come early in a career and then trail off. For instance, the mean gain this year for B.S. chemists aged between 20 and 29 and working for industry is 6.8%. For B.S.

Doctoral chemists earn about 50% more than their bachelor colleagues

Median salary, $ thousands[a]	Years since B.S. degree									Overall median
	2 to 4	5 to 9	10 to 14	15 to 19	20 to 24	25 to 29	30 to 34	35 to 39	40 or more	
ALL CHEMISTS	$31.5	$41.5	$51.0	$59.0	$64.0	$65.9	$68.0	$69.0	$71.5	$58.0
By sex										
Male	31.6	43.0	52.5	60.0	65.0	68.1	72.0	70.0	72.0	60.0
Female	30.5	39.0	45.9	53.0	52.1	55.0	54.0	52.0	55.6	45.4
By degree										
B.S.	31.0	38.0	44.0	51.0	54.0	58.2	56.0	64.1	65.0	44.4
M.S.	—	41.3	47.5	55.0	55.0	57.4	60.0	62.0	58.0	52.1
Ph.D.	—	52.8	56.0	63.3	69.0	72.0	73.0	72.0	75.0	65.0
By employer										
Industry	31.5	43.0	54.3	62.0	68.0	73.0	79.0	76.1	80.0	60.0
Government	—	37.2	47.4	58.0	53.5	62.0	65.4	59.0	71.0	56.0
Academia	—	31.0	37.5	42.3	43.5	55.0	56.3	60.0	63.0	50.1

a As of March 1, 1994. **Source:** ACS survey

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industrial chemists aged between 50 and 59, it is 3.6%. These mean individual increases reflect the growing experience and responsibilities of the people involved as well as any promotions they receive.

Information about professional income other than base salary shows a very skewed pattern. For instance, the new survey indicates a mean bonus for all respondents of $2,800, down from $2,900 in the previous year. However, the median is zero, as more than half received no bonus at all. Those in the upper 10 percentile had bonuses of $6,500 or more. Chemists working in industry are considerably more likely to receive bonuses than their colleagues in academia and government.

When overtime pay, consulting fees, and the like are included with bonuses, the mean of all extra professionally related income is $6,300, down from $7,800. More than 40% of respondents received nothing. The median is $1,200. Those in the top 10 percentile received $15,300 or more.

For the first time, this year's survey probes into the benefit plans and other fringe benefits chemists enjoy. At the top of the list, as reported by more than 90% of respondents, are holidays, annual leave, life insurance, and medical coverage for themselves and family. Less universal are sick leave (87%), dental coverage for themselves (85%), dental coverage for family (82%), accidental death insurance (77%), time off for jury duty (73%), a prescription drug program (71%), and long-term disability benefits (70%).

The latest survey indicates that the salaries of women chemists continue to creep closer to those of their male counterparts, but that progress is still a little spotty. For instance, after allowing for the generally greater professional experience of men, the mean salary of women B.S. chemists working for government is 99% that of corresponding men. At the other end of this spectrum, women Ph.D.s working for industry receive salaries only 85% that of their male counterparts. For all types of employers, women on average receive close to 90% the corresponding amount given to men.

According to the survey, women at all degree levels and within all major employment sectors—industry, academia, and government—made salary gains relative to men with one exception, women with doctorates working in industry.

A full report on this year's survey, "Salaries 1994," will be available in August at $150 per copy from the American Chemical Society, Distribution Office, 1155—16th St., N.W., Washington, D.C. 20036; phone (202) 872-4363. Questions about the survey should be directed to Burrelli at (202) 872-4433. ☐

Research, production garner lower salaries

Median salary, $ thousands[a]	By degree B.S.	M.S.	Ph.D.
R&D management	$63.0	$70.5	$88.0
General management	52.7	68.3	85.5
Marketing	50.4	58.0	75.0
Applied research	43.2	54.0	65.0
Production	42.0	49.4	64.9
Basic research	41.0	49.7	68.3

a As of March 1, 1994. **Source:** ACS survey

Salaries of smallest firms lag by more than 10%

Median salary, $ thousands[a]	By degree B.S.	M.S.	Ph.D.
NUMBER OF EMPLOYEES			
Less than 500	$40.0	$50.0	$66.0
500 to 2,499	44.8	53.0	69.0
2,500 to 9,999	48.6	55.0	70.0
10,000 to 24,999	51.5	60.0	72.0
25,000 or more	49.1	58.6	74.0

a As of March 1, 1994. **Source:** ACS survey

Big gap between Ph.D. and non-Ph.D. schools

	9- to 10-month contracts		11- to 12-month contracts	
Median salary, $ thousands[a]	Non-Ph.D. school	Ph.D. school	Non-Ph.D. school	Ph.D. school
Full professor	$52.0	$67.5	$76.5	$86.6
Associate professor	40.0	45.5	53.0	60.5
Assistant professor	33.6	40.8	44.3	46.8

a As of March 1, 1994. **Source:** ACS survey

House Votes To Cut Back Overall Federal R&D Funding In 1995

- ***Appropriations for NIH, NSF, and NIST would rise, but total R&D funding would decline 2% to $77.9 billion***

Janice Long, C&EN Washington

By burning a little midnight oil the House managed to complete its work on all of the fiscal 1995 appropriations bills that provide research and development funding before members left Washington for the Fourth of July recess. Working within some very stringent 1995 budget caps, the House found it necessary to reduce overall funding for R&D agencies by 2% to $77.9 billion. The bills now go to the Senate, but there isn't much hope that it will be any more generous than the House where research funding is concerned. In many cases, the Senate is working under even lower budget caps than the House was.

Some bright spots do exist in the House version of the R&D budget. For instance, funding for the National Institute of Standards & Technology would rise 62% to $842 million, and the National Science Foundation's total budget would be up 12% to $3.1 billion. However, those increases are more than offset by a 10% decrease, to $5.1 billion, in the Department of Energy's energy R&D budget, and a 2% decrease, to $35.1 billion, for Department of Defense R&D programs.

The House took a mere 15 minutes, late on the night of June 29, to approve a budget of $244 billion for DOD in fiscal 1995, a 1% increase over current DOD funding. Within the R&D allotment, which accounts for just 14% of the total DOD budget, funding for the Ballistic Missile Defense Organization (formerly known as the Strategic Defensive Initiative or Star Wars) would decline 18% to $2.0 billion, while funding for basic research would increase 4% to $1.25 billion.

However, the budget, as reported out of the Appropriations Committee and approved by the House, cuts all support, $828 million, for two of the Administration's pet programs—the defense reinvestment project and the manufacturing technology program—run by the Advanced Research Projects Agency. Also cut in half is the $1.8 billion request for university research.

As Rep. George E. Brown Jr. (D.-Calif.), chairman of the Committee on Science, Space & Technology notes, these cuts are aimed at programs that provide direct support for advanced technology development at DOD. These include areas such as laser and optical sciences, materials science, applied mathematics, and computer science. The same fields are among the areas of emphasis laid out by President Clinton in his technology initiatives. In short, Brown said, "If these cuts stand, they will directly undermine DOD's science and technology strategy and the President's technology plan."

Furthermore, he points out, the university cut would severely damage academic research institutions that depend heavily on DOD support. Among the top 10 recipients of that support are the University of Texas, Massachusetts Institute of Technology, Johns Hopkins University, Georgia Institute of Technology, and Stanford University. Brown notes that "the silence on this cut is deafening. . . . We hear no howls and no rage." That, he believes, is because "All of use here in this body assume, and I think correctly, that this problem will go away in the Senate and in conference, and the money will be restored."

Some believe the defense appropriations subcommittee, chaired by Rep. John P. Murtha (D.-Pa.), took aim at university research because of an ongoing dispute with Brown over academic earmarks. Science committee staff have found at least $67 million in academic earmarks in the current DOD bill, according to Brown, and there are probably a lot more that haven't been detected yet. Those found so far include $18 million to the University of Pittsburgh for the National Defense Center of Environmental Excellence, $10 million for the San Diego State University Conversion Center, and $4 million for the University of New Orleans Advanced Marine Technology Center.

Preceding the DOD appropriations bill on the House's June 29 schedule, the Departments of Veterans Affairs and Housing & Urban Development, and Independent Agencies 1995 appropriations bill generated more debate—about seven hours worth—among House members. However, few changes were made to the bill, which funds the National Science Foundation, National Aeronautics & Space Administration, and the Environmental Protection Agency.

Under the bill, total NSF funding would rise substantially from 1994, with funding for research and related activities up 11% to $2.2 billion, versus the 18% increase sought by the Administration. The bill cuts in half the requested increase of $66 million for global-change research, leaving it with a still healthy 23% increase to $175 million. The bill also cuts $29 million from the $62 million increase requested for the high-performance computing and communication initiative, leaving it with a 12% increase to $300 million. The Appropriations Committee took these actions because of concerns that "these new initiatives are being funded at the expense of significant and ongoing research efforts." The bill also does not include the one-year freeze in the payment of indirect costs to academic institutions requested by the Administration.

During the debate on the VA-HUD bill, the House easily defeated, 278 to

Cuts in defense, energy research drag down '95 R&D budget

$ Millions	1994	1995 Administration request	1995 House appropriation	% difference, appropriation-request	% change 1994–95
Defense	$35,888	$35,962	$35,137	–2%	–2%
Development	26,327	26,652	26,303	–1	0
Operational systems	11,474	10,906	12,210	12	6
Engineering & manufacturing	7,441	8,916	7,758	–13	4
Advanced	4,669	3,846	3,248	–16	–30
Exploratory	2,743	2,984	3,087	3	13
Management & support	3,218	3,079	3,077	0	–4
Demonstration & validation	2,698	2,566	2,507	–2	–7
Ballistic Missile Defense Organization	2,440	2,440	2,002	–18	–18
Basic research	1,205	1,225	1,249	2	4
General reduction, university research	—	—	–1	na	na
NASA	15,113	14,284	14,044	–2	–7
Science, aeronautics & technology	5,788	5,901	5,901	0	2
Human space flight	6,672	5,720	5,593	–2	–16
Mission support	2,653	2,663	2,550	–4	–4
Energy	12,742	12,168	11,796	–3	–7
Environmental restoration & waste management	5,899	5,961	5,872	–1	0
Energy R&D	5,706	5,411	5,147	–5	–10
General science & research	1,615	1,110	989	–11	–39
Superconducting Super Collider termination costs[a]	640	180	0	na	na
Supporting research & technical analyses	976	956	943	–1	–3
Materials sciences[a]	277	274	277	1	0
Chemical sciences[a]	169	162	165	2	–2
Waste R&D	687	703	703	0	2
Conservation	385	588	482	–18	25
Biological & environmental research	416	435	435	0	4
Fossil	431	451	429	–5	0
Solar & renewables	347	398	402	1	16
Fusion	348	373	377	1	8
Nuclear	341	248	260	5	–24
Environment, safety & health	160	149	127	–15	–21
Weapons R&D	1,137	796	777	–2	–32
NIH	10,938	11,471	11,322	–1	4
National Institutes	10,001	10,433	10,302	–1	3
General Medical Sciences[a]	876	908	902	–1	3
National Center for Research Resources	332	351	358	2	8
National Center for Human Genome Research	127	152	152	0	20
Other	478	535	510	–5	7
NSF	2,796	3,199	3,141	–2	12
Research & related activities	1,993	2,348	2,217	–6	11
Education & human resources	570	586	586	0	3
Major research equipment	—[b]	70	105	150	na
Academic research infrastructure	105	55	100	82	–5
Other	128	140	133	–5	4
USDA	1,416	1,365	1,366	0	–4
Agricultural Research Service	728	743	717	–3	–2
Cooperative State Research Service	495	419	448	7	–9
Forest research	193	203	201	–1	4
Commerce	747	1,166	1,080	–8	45
National Institute of Standards & Technology	520	935	842	–10	62
Oceanic & atmospheric research	227	231	238	3	5
TOTAL	$79,640	$79,615	$77,886	–2%	–2%

[a] Funds included in preceding total. [b] Data not available. **na** = Not applicable.
Source: House Appropriations Committee reports

155, an amendment that sought to prohibit spending the $2.1 billion provided for the space station and instead direct the funding to other NASA programs. Last year, an attempt to eliminate the space station and use its funds for deficit reduction failed by only one vote. Overall, the bill provides NASA with $14.0 billion, a 7% decrease from current funding levels. It's hard to tell how much of that would fund R&D activities because NASA has changed its budget accounts and no longer has a category entitled R&D. This year 40% of the human space flight budget is going for R&D activities, as is 81% of the science, aeronautics, and technology budget, and 14% of the mission support budget.

EPA has also changed its budget accounts, mixing together the old R&D and abatement, control, and compliance accounts. For what it's worth, funding for the new account—research, prevention, and program activities—would fall 5% to $1.6 billion.

The appropriations bill that funds the National Institutes of Health also was approved by the House on June 29. Under the bill's provisions, NIH would receive a 4% budget increase, rather than the Administration's request for 5%, to $11.3 billion. Funding for the National Institute of General Medical Sciences, which provides the majority of NIH's funding for chemical research, would rise just 3% to $902 million, but funding for the National Center for Research Resources would increase 8% to $358 million. Included in that amount is $20 million, to be awarded competitively, for renovation and construction of extramural biomedical facilities.

Although NIH's increase probably wouldn't allow it to keep up with inflation, the agency fares better than the Department of Energy, whose House-approved budget would fall 7% to $11.8 billion. Funding for weapons R&D would be down 32% to $777 million. If the figures in the House bill hold up, fiscal 1995 would mark the first year DOE would spend more on cleaning up its messes from past activities—$5.9 billion—than it does on R&D.

The House has also approved a cut of 4% to $1.4 billion for the Department of Agriculture's research programs, and an increase of 45% to $1.1 billion for those at the Department of Commerce. ☐

New details on nuclear weapons program bared

In a continuing effort to be more candid about Department of Energy nuclear weapons programs, Energy Secretary Hazel R. O'Leary recently declassified a substantial amount of information. On June 27, she revealed details about total U.S. weapons-grade uranium production, testing of a bomb made of reactor-grade plutonium, radiation experiments conducted on humans since the 1920s, and underground and atmospheric nuclear weapons tests.

O'Leary explains the new revelations by saying thousands of people in meetings across the country this year have told her that "openness in government is very important. We are responding today in a manner that both satisfies the strong public interest and respects critical national security requirements."

The total U.S. production of highly enriched weapons-grade uranium is 994 metric tons, O'Leary says, far more than the 700 metric tons previously estimated by outside experts. Almost 259 metric tons remain in the U.S. stockpile, most of it stored at the DOE facility in Oak Ridge, Tenn. Most of the remaining 735 metric tons is contained in the weapons themselves. (Weapons-grade uranium is defined as at least 20% ^{235}U, with the remainder ^{238}U, but most of that produced for weapons is at least 90% ^{235}U.) It takes only about 25 kg of weapons-grade uranium to make a crude nuclear device.

DOE and the Department of Defense are now in the process of deciding how much of the weapons-grade uranium stockpile is surplus and what to do with it. Eventually, the surplus weapons uranium may be mixed with ^{238}U and used to fuel commercial nuclear power plants.

The testing of a bomb made of reactor-grade plutonium was known previously, but not the year, 1962, or the explosive power, less than 20 kilotons. Revelation of the test should convince people that plutonium extracted from spent commercial power plant fuel can be made into bombs. French, British, and Japanese nuclear power officials routinely assert that civilian plutonium has no strategic value. And the British government only recently said the 1962 test was "alleged to have been carried out" and refused to comment on it,

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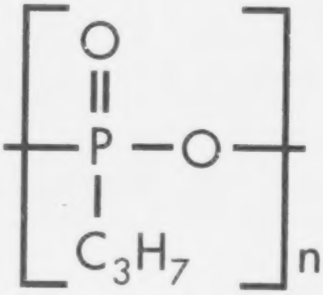

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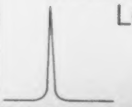

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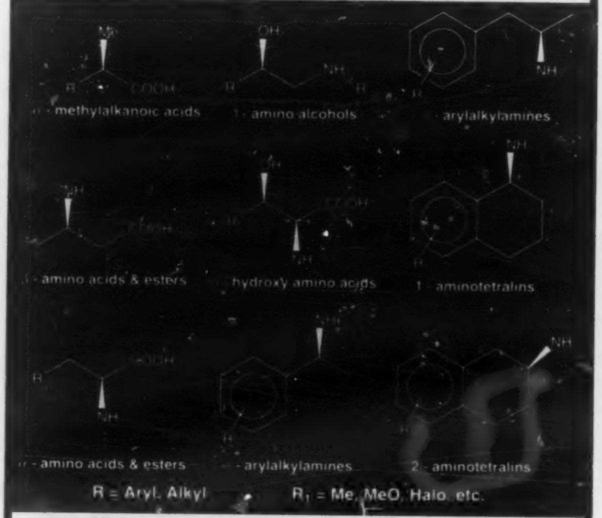

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even though it had supplied the plutonium for the test.

"Secretary Hazel O'Leary is to be congratulated for declassifying the important information that should lay to rest, once and for all, this dangerous misunderstanding," says Paul L. Levanthal, president of the Nuclear Control Institute (NCI) in Washington, D.C. NCI is a think tank to develop strategies for stopping the spread of nuclear arms.

O'Leary has not specified the size of the current U.S. nuclear weapons arsenal, but has disclosed its size in 1961—22,229 warheads. She also reveals that 17,187 weapons were dismantled between 1980 and the beginning of 1994.

In 1986, Rep. Edward J. Markey (D.-Mass.), then chairman of the House Energy & Commerce Subcommittee on Energy Conservation & Power, released a report giving details about experiments in which individuals were intentionally exposed to ionizing radiation.

O'Leary has released information about 48 additional tests not included in the Markey report. About half of these were secret until O'Leary's disclosure. The 48 tests involved as many as 1,200 people and were conducted at hospitals and universities across the country from the 1940s to the present. No medical benefit was expected from any of these tests, and for most, there is no record that the subjects were fully informed.

In one test, healthy pregnant women were given tracer amounts of ^{59}Fe, ranging from 1.8 to 120 mg. A small increase in cancer incidence was found in their offspring—three cases in 634 exposed children compared with none in the controls.

DOE points out that this current list "represents only a small fraction of the total number of experiments that were conducted." It expects that more tests will be added to the list in the future by a Presidentially appointed advisory committee that is investigating this issue.

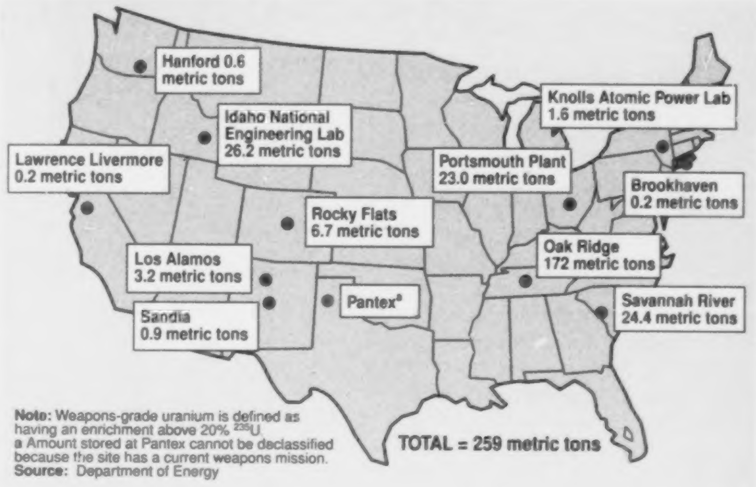
O'Leary also disclosed that the total number of nuclear weapons tests was 1,054, three more than announced previously. In addition, O'Leary revealed that 20 of the 828 underground tests conducted between 1961 and 1986 at the Nevada test site leaked radiation to the environment. The National Cancer Institute studied thyroid disease in populations exposed to the radiation from these tests and concluded in 1992 that thyroid cancer increased with exposure to ^{131}I radiation resulting from the tests.

Between 1946 and 1962, 67 atmospheric bomb tests were conducted in the Marshall Islands in the Pacific. O'Leary made public 460 previously classified records on these tests, including data on the 1954 test "Bravo" that had the explosive power of 1,000 Hiroshima-type atomic bombs and resulted in heavy contamination of several islands.

DOE is now indexing everything it has declassified since 1946 and putting it on Internet so it will be easily accessible.

Bette Hileman

Substantial quantities of weapons-grade uranium are stored at 12 Department of Energy sites


Hanford 0.6 metric tons
Idaho National Engineering Lab 26.2 metric tons
Lawrence Livermore 0.2 metric tons
Knolls Atomic Power Lab 1.6 metric tons
Portsmouth Plant 23.0 metric tons
Brookhaven 0.2 metric tons
Rocky Flats 6.7 metric tons
Oak Ridge 172 metric tons
Los Alamos 3.2 metric tons
Pantex[a]
Savannah River 24.4 metric tons
Sandia 0.9 metric tons
TOTAL = 259 metric tons

Note: Weapons-grade uranium is defined as having an enrichment above 20% ^{235}U.
a Amount stored at Pantex cannot be declassified because the site has a current weapons mission.
Source: Department of Energy

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CHEMICAL & ENGINEERING NEWS

C&EN

JULY 18, 1994

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FLUORESCENCE IMAGING

Technique tracks messenger
molecules in living cells
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NEWS OF THE WEEK

- The cost of producing ethylene may be lowered by a new process that replaces energy-intensive demethanization and cryogenic separations with a solvent absorption process. Page 6
- U.S. government agrees to give France's Pasteur Institute a larger share of AIDS test royalties—and acknowledges that NIH scientists used a Pasteur-provided virus to develop the U.S. test. Page 7
- Monsanto and Chevron Chemical are sued for age and racial discrimination by 41 former employees of Chevron's Ortho division, which was purchased by Monsanto. Page 7
- Hercules, looking to focus on specialty chemicals, arranges sale of its aerospace businesses to Alliant Techsystems. Page 8
- China, the U.K., and the U.S. garner top three rankings in 26th International Chemistry Olympiad—with the U.S. team winning two gold, one silver, and one bronze medal. Page 8
- Formosa Plastics signs agreement with regulatory and environmental groups to fund study aimed at achieving zero discharge in wastewater from its plant on the Gulf Coast. Page 9

COVER: Fluorescence imaging shows a cytotoxic T lymphocyte killing a target cell with an overdose of Ca^{2+}. Photo courtesy of Marc Poenie et al., *EMBO Journal*, 6, 223, (1987); reprinted by permission of Oxford University Press

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BUSINESS

Engineering firms, contractors say alliances are crucial to success in developing new business as their clients, including chemical companies, cut back on capital expenditures. Page 14

Basofil, a new high-performance fiber to be introduced by BASF in 1996, will meet stiff competition in the crowded market for heat- and flame-resistant fibers. Page 17

GOVERNMENT

Antidumping laws, countervailing duties, and fast-track negotiating authority are some issues Congress, Administration must resolve to pass legislation to implement GATT trade pact. Page 21

Council on Competitiveness index report notes that U.S. economy is stronger but that major challenges still lie ahead. Page 22

SCIENCE/TECHNOLOGY

Interference with melatonin, disruption of cell communication at gap junctions are some hypotheses proposed to explain the complex physiological effects of electric and magnetic fields. Page 27

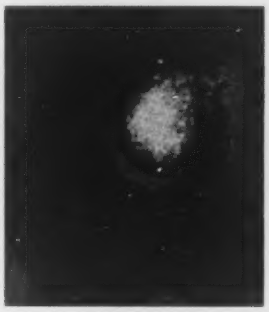
ACS NEWS

ACS Council will consider petitions to amend the society's governing documents on elections and membership requirements when it meets next month in Washington, D.C. Page 46

FINAL PROGRAM

ACS national meeting in Washington, D.C., will include nearly 5,200 papers in more than 550 technical sessions; exposition will comprise about 385 booths, more than 230 exhibitors. Page 53

SPECIAL REPORT



Advances in the design and synthesis of fluorescent molecules that reversibly bind chemical messengers in living cells allow researchers to observe the dynamics of a cell's internal biochemistry. Page 34

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Editor: Michael Heylin (202) 872-4501
Managing Editor: Madeleine Jacobs
Assistant Managing Editors: Ernest L. Carpenter, James H. Krieger, Janice R. Long, Rebecca L. Rawls, William J. Storck
Senior Correspondents: Lois R. Ember, Wilbert C. Lepkowski
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News Bureaus: Northeast: (908) 906-8300 Ann M. Thayer (Head), Elisabeth Kirschner (Assistant Editor), George Peaff (Assistant Editor), Rachel Eskenazi (Administrative Assistant). Houston: (713) 558-2912 Susan J. Ainsworth (Head). Washington: (202) 872-4495 David J. Hanson (Head), Raymond A. Goodlett (Intern). West Coast: Rudy M. Baum (Head), (206) 517-5034 Deborah L. Illman (Associate Editor). London: (01) 44 81 870-6884 Patricia Layman (Senior Editor), (01) 44 256-811052 Michael Freemantle (Senior Editor)
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LETTERS

Iron-age catalysis

The April 18 issue of C&EN (page 22) continues the currently popular story of the great contribution of catalysis to environmentally benign chemical process design. I fear that the concept is being oversold at the expense of scientific credibility and integrity.

For example, a chart on page 24 compares the catalytic and the conventional (presumably noncatalytic) routes for the preparation of hydroquinone. Unfortunately, the conventional method has three catalytic steps: the acid-catalyzed nitration of benzene to nitrobenzene, the catalytic hydrogenation of nitrobenzene to aniline, and the catalytic hydrogenation of quinone to hydroquinone.

The two hydrogenations are quaintly, and misleadingly, shown in the chart as reductions with iron and hydrochloric acid. Only an ancient catalytic chemist like myself could recall when iron and hydrochloric acid were used industrially for such purposes!

Harold Greenfield
HGV Consulting Co.
Green Valley, Ariz.

Cut short

Michael Heylin's interesting editorial (C&EN, May 9, page 3) on common usage of the word "chemical" to mean synthetic chemical throws a new light on the continuing discussion in C&EN (spiritual versus chemical was suggested by A. R. Patton [C&EN, May 30, page 3]). Heylin rightly points out that this usage "is a cultural, linguistic thing."

The problem occurs because we often shorten expressions by throwing away the more descriptive parts. Thus a graphite-reinforced tennis racket is advertised as 100% graphite. And because the expression "explosive bomb" has been shortened to simply bomb, chemists must be careful about using the word bomb to describe a reaction vessel.

Of course, this sort of thing is not limited to chemistry. Execution of the death penalty is shortened to execution. Whole-wheat bread becomes wheat bread (as opposed to white bread, which, presumably, is not made of wheat), and the United States of America is shortened to America.

Alan R. Miller
Professor of Metallurgy
New Mexico Tech
Socorro, N.M.

A pause on environmental policy

In its report on dioxin, the Environmental Protection Agency makes an astounding about-face on cancer risk (C&EN, May 16, page 36). After 30 years during which cancer risks have driven environmental policy out of any political control, EPA now finds there are no cancer risks, at least for dioxin. Tens of billions of dollars in mandated spending and a thousand new rules in 1993 alone have no other justification than the controversial cancer risks that EPA has been calculating.

Instead, EPA now cites health effects on fetal development and the immune system. But fetal and immune risk cannot soon play the regulatory role that cancer risk has played and probably never will. Any quantitative fetal risk assessment would require "assumptions" as controversial as those currently used in "quantitative cancer risk assessment." Those assumptions are now severely criticized. Without them, there is no fetal risk of dioxin in humans just as there never was a cancer risk.

Congress now struggles to reclaim some control over environmental policy, which it lost with assumed risks. By coincidence, the Superfund reauthorization cleared its first Congressional hurdle on the same day that EPA dumped dioxin cancer risk. Many consider Superfund the worst piece of legislation ever passed by Congress because it legitimized the assumption of risks. This time around, Congress should pause before jumping and ponder the wisdom of a policy based on risks that exist one day and are gone the next.

We recommend that Congress suspend Superfund and related laws for five years so that the public and elected officials can absorb the dioxin fiasco. This is a time for

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Tight Chemical Market Spurs New Services At Engineering Firms

■ *Alliances with clients and competitors, plus global computer networks, boost contractors' opportunities for business development*

Susan J. Ainsworth, C&EN Houston

These days, going to the company board of directors to sell them on plans to build a new plant or upgrade an existing one ranks right up there with chemical business managers' most dreaded tasks. Over the past few years, in a chemical market characterized by wafer-thin profit margins and minuscule demand growth, chemical company management has spent much more time and energy devising ways to delay capital expenditures.

Not only has investment in new and existing plants dropped, but chemical companies also have whittled down their internal engineering departments and rigorously cut costs within those projects they do undertake. This scenario has, in turn, created challenges for the engineering and construction firms that serve the chemical, plastic, and pharmaceutical industries.

But many engineering and construction firms say they have found ways to create opportunity out of these challenges. Basically, contractors are becoming more attuned to companies' needs and moving quickly to meet them, even if it means extending themselves into new areas of service.

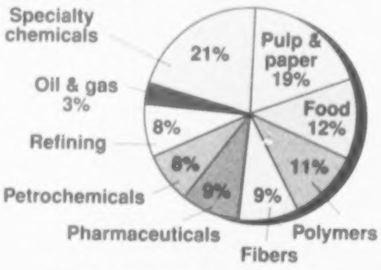
Most notably, contractors are teaming up with clients in alliances to take on any tasks chemical companies can no longer handle internally. They are also forming alliances with their competitors to meld expertise and create synergies that more precisely fit the client's needs. These firms are also creating global offices through information technology computer systems to better capture growth in the specific regions in which chemical companies are now expanding.

These new strategies benefit not only the engineering and construction firms that use them to the best advantage but also their chemical company clients, which are now enjoying a broader range of services and more value for their dollar. What's more, these market changes, made in the heat of the recessionary bust, will serve both client and contractor well as they anticipate recovery that they say will stop just short of another building boom.

"Business is spotty now, but I think [the number of projects] will begin to pick up across the board," says Harvey J. Rosenfeld, executive vice president of Houston-based John Brown Engineers & Constructors. "Our customers are becoming more bullish about investment, particularly in polymers. I'm convinced that two of our biggest polymer clients are going to come out of the downturn with a bang." Next year, John Brown expects to be bidding on a polyethylene plant for one of those companies and on a polypropylene unit for the other.

Jerry Oliver, vice president and manager of technology for Houston-based Bechtel Petroleum, Chemical & Industrial Co., has also observed increasing interest in plastics projects lately. Particularly hot are plans for polyethylene terephthalate, polyvinyl chloride, and purified terephthalic acid, which is used to produce polyester, he says.

Specialty chemicals are a big construction market



1993 total for U.S. projects[a] = $47 billion

[a] For chemical and related process industries.
Source: John Brown Engineers & Constructors

Houston-based engineering firm M. W. Kellogg reports more activity further upstream—its area of expertise. "We don't see as many inquiries for new projects as we'd like to see, but [we] do have the perception that business is turning around, particularly on the ethylene side," says Martin J. Van Sickels, vice president and director of technology management at Kellogg. His colleague Rolf C. Nedelmann, director of sales administration, adds: "If our projections are right, we will see some ethylene capacity additions toward the second half of the 1990s. These expansions will probably be accomplished through debottlenecking of facilities built in the past decade rather than through building of new grassroots plants."

Kellogg's manager for market analysis and planning, Art Kelly, observes that the firm has seen a steady stream of environmental projects, many of which are driven by government regulations. For example, "We've prepared some environmental impact statements for our clients and helped them with analyses that are needed to ensure their compliance with the Clean Air Act." These mandatory expenditures have helped to broaden engineering firms' sales bases through the market downturn, when chemical companies could not justify expenditures on production plants.

The revenues engineering firms have lost to fewer expansion projects are being made up at least partly as they are asked to fill voids left by downsizing programs at chemical companies. For example, contractors are taking on project implementation, production design, and construction management—work that used to be done by the engineering staffs of chemical companies.

Because contractors are becoming more intimately involved in chemical projects, clients are setting up alliances with engineering firms in which each party is more closely attuned and committed to the other's business goals. Among other things, the alliance guarantees that the client will have a trained work force when business starts to pick up again, says John Brown's Rosenfeld.

In addition to allowing chemical companies to stabilize their work force and cut fixed costs, "alliances give us an opportunity to better capitalize on engineering firms' strengths," says Vic Kleinfelter, engineering manager for design at Wilmington, Del.-based DuPont. "They can provide more value than they could have in the past." Alliances are more open, trusting, and performance-oriented than the partnerships DuPont set up with contractors back in the mid-1980s, he observes. Another difference: Alliance contractors are paid on the basis of the value they add to the clients' business rather than on the number of hours logged on a project.

Clients are asking their alliance contractors to be involved earlier in the process, too. "In the past," says Kleinfelter, "we might have given a contractor a set of specifications and drawings for a plant with instructions to build it at the lowest possible cost. Now, we want to bring the contractor in on the front end so we can utilize its expertise and its unique window on the outside world." Although a chemical company understands the basic chemical production process better than anyone, the engineering firm often can bring in new technologies for reducing emissions, capital costs, or energy consumption that are valuable as the process is scaled up, he says.

Kellogg's Nedelmann sees this trend, too. Clients "are coming to us even before they know whether the project will pan out, because they know that the contractor's expertise can significantly reduce a client's capital investment on a project."

DuPont's Kleinfelter adds: "There's no question that strategic alliances between chemical companies and engineering firms are on the rise. We are just beginning to tap all the opportunities."

Licensing alliances between chemical companies and engineering and construction firms are taking off too, because they can be mutually beneficial. Licensing alliances help each partner leverage its resources to achieve business goals that would have been more difficult to achieve alone, says Jeffrey P. Reilly, manager of strategic business development for technology businesses in Houston for Bloomfield, N.J.-based ABB Lummus Crest. Through such an arrangement, companies can more successfully share skills and costs, gain access to new markets, or reduce a company's reaction time to uncertain events, he adds.

Mobil Chemical polyethylene unit in Beaumont, Tex., built by John Brown.

Chemical companies cannot afford to miss out on the revenue that a desirable technology can generate, but because they are operating with reduced internal staffs, they cannot get technology licensed out as efficiently as they used to, says Bechtel's Oliver. The obvious solution is to align with an engineering firm that can take on some of the engineering and licensing work.

Just last month, Kellogg signed an exclusive licensing agreement to market Dow Chemical's bisphenol A technology and build plants based on it. The Dow bisphenol A process provides a high-quality feed for making specialty polycarbonate products with the lowest yellowness index at both low capital and manufacturing costs. For Dow, the alliance represents an opportunity to generate new sales growth for a technology that has never been offered outside the company before. At the same time, it allows Kellogg to add to its other technology offerings in the phenol process chain.

"Traditionally, we have not worried much about getting into licensing alliances," says Oliver, "but now that we see that they represent a real revenue-generating opportunity, we are looking closely at whom we should be aligning with."

Engineering and construction firms are also teaming up with competitors to bring together services tailored specifically to prospective clients' needs. For example, in April, Brown & Root and Chemicals & Kinetics Technology International formed a strategic alliance to jointly offer their services to ethylene producers. Together, the partners will bring to the alliance ethylene production technologies that will allow them to build plants with the most reliable yield prediction and the lowest possible capital and energy requirements, according to Wilfred K. Lam, vice president for process technology at Brown & Root.

Teaming up with competitors can also give engineering and construction firms a stronger foothold in another part of the world. For example, earlier this month, Lebron Associates, a Puerto Rican architectural and engineering consulting firm, and John Brown entered into an exclusive working arrangement to provide the full range of engineering, construction, and validation services to the pharmaceutical and fine chemicals industry in Puerto Rico. John Brown brings world-class technologies; a global information and communication network; and extensive validation, construction management, and process-engineering expertise to the agreement. At the same time, Lebron provides a thorough understanding of Puerto Rico's environmental issues and architectural and engineering requirements. Through this arrangement, the team addresses the rapidly changing and more competitive conditions facing the pharmaceutical industry in Puerto Rico by delivering more cost-effective and sophisticated facilities on a faster schedule.

Forming contractor alliances is just one way contractors are trying to tap the brisk growth in demand for chemicals in select areas outside the U.S., such as the Pacific Rim and Latin America. They recognize that to compete on the global playing field they must be as international as their clients.

"You have to understand the various government regulations, financing issues, and market dynamics unique to each area if you want to win projects," says Oliver. In keeping with that philosophy, Bechtel just completed a market study for Thailand's government suggesting which ethylene-based chemicals and plastics the country should be most interested in expanding into so that it can build an infrastructure. "This work is extremely resource-intensive," he says, "but there's no shortcut for it."

John Brown's Rosenfeld echoes this point. Contractors must know the local customs and consider, for example, the religious mix of a region in hiring and training workers. John Brown recognizes the importance of having people native to a region in sites and managing offices. Having grown by acquisition, the company and and its parent, London-based Trafalgar House Engineering, now own a great number of small sites around the globe. Most of their rivals, in contrast, have a small number of very big sites. "So having a local presence is one of our strengths," says Rosenfeld.

At the same time, John Brown knows it's not practical or economically feasible to put experts in every aspect of engineering at every one of its 35 major offices in 30 countries. It needs the local element, but it also needs to link those regions so that expertise is readily accessible to all its engineers. With this consideration in mind, the firm has developed a high-speed computer network that links all the company's sites so that they operate as one global office, says Bill Mitchell, information technology program manager at John Brown in Houston.

Although the network has been in operation for roughly five years, just this past September, the company added some more powerful components that allow engineering applications to be transmitted over the network. One application, called Engines, enables employees on different continents to work simultaneously on different stages of a project rather than doing them in sequence, says Mitchell. As a result, John Brown can essentially put in a 24-hour workday for its clients. For example, an engineer in London can check and correct the work of a colleague in Houston by using on-line annotation or pasting on an electronic note while the engineer in the U.S. sleeps.

Van Sickels: business is turning around

With this system, John Brown has been able to reduce project timetables and serve clients from anywhere in the world. It also saves on travel costs and cuts down on the number of costly mistakes, because the system can be programmed to check safety and design specifications, he says.

Engineering firms' leadership in these types of technologies is becoming an increasingly important criterion for chemical companies, says DuPont's Kleinfelter. For example, John Brown's information technology capabilities were an important element in DuPont's decision just a few months ago to contract with JBEK—an alliance formed between John Brown and BE&K, a Birmingham, Ala., construction firm. "We want the engineering firms we work with to bring information technology, networks, and 3-D design capabilities to our business to help us reduce the overall cost and cycle time of our engineering and construction work while increasing its quality," says Kleinfelter.

C&EN staff photo

Rosenfeld: services must not be gimmicks

In another move aimed at gaining an edge in the chemical market, contractors have had to change the way they bid for projects. Instead of bidding on a cost reimbursement basis (giving an estimate of costs up front and being compensated for any costs over that estimate), clients now want contractors to bid on a lump-sum amount and absorb any additional costs over the initial figure. "They are asking us to lay it on the line, give a competitive low bid to win the project, and take all the risk," Oliver says. "All firms like ours must operate this way to compete."

Because lump-sum bidding allows a client to lock in its total-cost figure early on, it makes it easier for the client to secure financing. Clients are also looking to engineering firms to help them with their financing plans in a more direct way. For example, a client might go as far as asking a contractor to take an equity interest in a project or even help arrange financing, says Oliver. "They want us to be a full-service house—to provide whatever they need to do a particular project."

Another way contractors hope to woo prospective clients is by earning credentials for international quality management standards. Chemical companies in the U.S. are not yet requiring ISO 9000 registration as a prerequisite to bidding on a project, but contractors anticipate that this will occur in the near future. "We viewed [not being ISO certified] as a threat to our business," says Kellogg's Van Sickels, noting that in June Kellogg became one of only a few contractors to receive ISO 9001 certification across the broad spectrum of contractor capabilities.

Engineering firms' new slate of services and marketing tools—from ISO standardization to information technology to alliances—have to be much more than gimmicks, says Rosenfeld. They have to be effective in helping improve investment productivity for the client, he adds. "The bottom line is that we have to get costs down and build plants faster. To compete in this market, you've got to have all the bells and whistles and the low price, too." ☐

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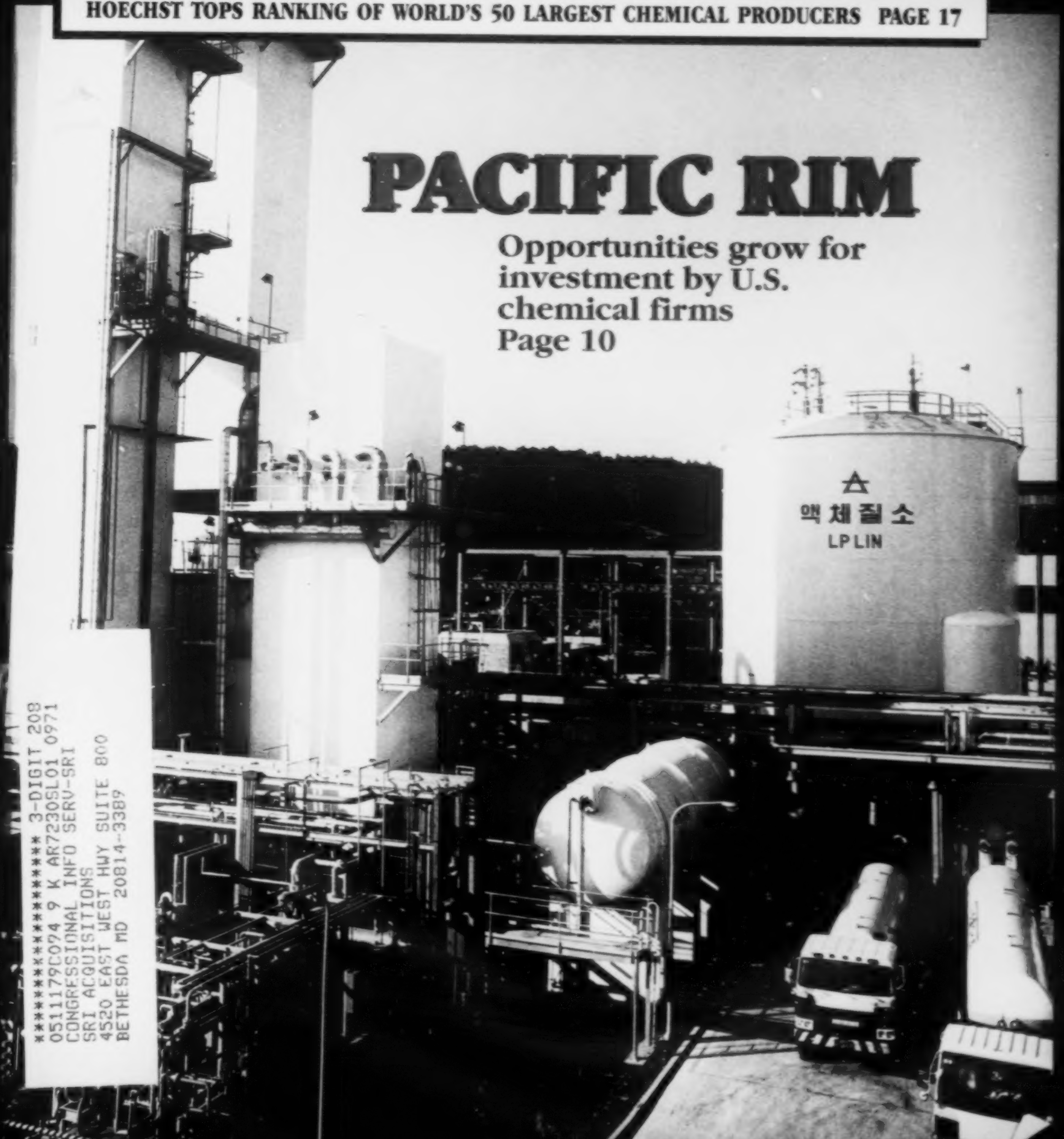
HOECHST TOPS RANKING OF WORLD'S 50 LARGEST CHEMICAL PRODUCERS PAGE 17



PACIFIC RIM

Opportunities grow for investment by U.S. chemical firms
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JULY 25, 1994

NEWS OF THE WEEK

- Comet Shoemaker-Levy 9's dazzling impact on Jupiter generates wealth of information, including surprising spectroscopic detection of diatomic sulfur (S_2) in Jovian atmosphere. **Page 6**
- Researchers use laser-excited xenon in a technique that opens up potential for in vivo magnetic resonance imaging of lung, brain, and other human organs. **Page 7**
- Union Carbide and Petrochemical Industries Corp. of Kuwait award contract to Fluor Daniel for engineering, procurement, and construction of a $1 billion petrochemical complex in Kuwait. **Page 8**
- Synergen faces uncertain future, price of stock plunges as company halts development of its flagship product, the antisepsis drug Antril, after disappointing clinical trials. **Page 8**
- At celebrations marking the 25th anniversary of the Moon landing, Administration reiterates commitment to space program, innovation, and pursuit of knowledge. **Page 8**
- EPA shifts approach to environmental regulation; through the Common Sense Initiative, focus will be on overall impact of entire industries rather than on individual pollutants. **Page 9**

COVER: Air Products & Chemicals jointly owns industrial gases complex in Onsan, South Korea, with partner Korea Industrial Gases

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BUSINESS

Hoechst ranks first among world's 50 largest chemical producers for 1993, a year in which the industry posted lower sales as it struggled against low prices and currency fluctuations. **Page 17**

GOVERNMENT

Controversial changes in NIH's grant approval process are being considered, and some are being tested, as the agency eyes goal of doing more with its resources. **Page 20**

More regulation of dioxin emissions is needed, say two activist groups that cite biological effects from ingestion of minute quantities of chemicals. **Page 21**

SCIENCE/TECHNOLOGY

The outcome of a recent commercial catalyst and process industry conference may help chart a course for revitalization of industrial catalysis research and development. **Page 25**

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ACS Industrial & Engineering Chemistry Division's Symposium on Emerging Technologies in Hazardous Waste Management features over 650 papers, various workshops. **Page 43**

Polymer Chemistry Division's 17th Biennial Symposium on Polymers in Critical Technologies will be held in November in San Juan, Puerto Rico. **Page 52**

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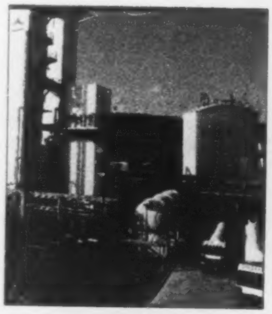

U.S. chemical companies boost investments in fast-growing Pacific Rim region, despite infrastructure problems and economic and political uncertainties in some countries. Page 10

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Editor: Michael Heylin (202) 872-4501
Managing Editor: Madeleine Jacobs
Assistant Managing Editors: Ernest L. Carpenter, James H. Krieger, Janice R. Long, Rebecca L. Rawls, William J. Storck
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LETTERS

Ethics, responsibility in science

Both your editorial "Responsible Science" (C&EN, June 27, page 3) and the news article on page 7 offer self-congratulations on the uncovering of fraud in a report of the enhancement of enantioselectivity by a magnetic field. The matter is described as "an example of good science" that purified itself in only four months.

Not only was much time and effort wasted by others attempting to replicate the reported results, this time the fraud cannot be dismissed as being in medical science. Since it was in physical science, it reflects on all of us, and on how the public perceives the way our science works and how we behave.

Extraordinary claims demand extraordinary evidence, and evidence that can be manipulated by a single graduate student is not extraordinary. A large share of the responsibility rests on the professor in charge, who should have supervised and demanded iron-clad evidence. We have already learned from the polywater, cold fusion, and immunological dilution episodes that editors of some scientific journals are more interested in publicity than reliability.

R. Bruce Martin
University of Virginia
Charlottesville

Your report concerning the unfortunate claim that enantioselective reactions had been achieved in a static magnetic field [Guido Zadel, et al., *Angew. Chemie*, **33**, 454 (1994)] brings forth the following question: What was the reasoning behind the experiment to begin with?

Studies by Pierre G. de Gennes [(*C. R. Hebd. Seances, Acad. Sci. Ser. B*, **270**, 891 (1970)]; C. Alden Mead, et al. [*Tetrahedron Lett.*, 1063 (1977)]; and Mead and Albert Moscowitz (*J. Am. Chem. Soc.*, **102**, 7301 (1980)] have provided theoretical reasons why the experiment should not produce the desired result. To quote Mead and Moscowitz: "We recently showed . . . that asymmetric synthesis at thermal equilibrium cannot be brought about by any combination of uniform, static electric, and magnetic fields." Moreover, in this same paper, they concluded that earlier claims by Ralph C. Dougherty [*J. Am. Chem. Soc.*, **102**, 380 (1980)] and Dougherty, et al. [*J. Am. Chem. Soc.*, **102**, 380 (1980)] of having achieved asymmetric synthesis from achiral reagents in a rotating vessel "is entirely without any foundation and cannot be taken seriously as an explanation for the data reported."

Finally, concerning the work of Pierre Curie on symmetry and asymmetry quoted by Zadel, et al., there is a charming description by his wife, Marie, in her biography of Pierre "Pierre Curie," Macmillan Co., New York, 1923, page 55), which indicates he was aware of the negative results to be expected by experiments of that sort.

To quote her own quote of his conclusions reached between 1893 and 1895: "When certain causes produce certain effects, the elements of symmetry in the causes ought to appear in the effects produced. When certain effects reveal a certain dissymmetry, this dissymmetry should be apparent in the causes which have given them birth. The converse of these two statements does not hold, at least practically; that is to say, the effects produced can be more symmetrical than their causes."

The papers cited in my second paragraph demonstrated, nearly two decades ago, that the application of such fields should have no effect on the outcome, as was clearly envisioned by Pierre Curie exactly 100 years ago.

Ivan Bernal
University of Houston

Scientific integrity is in the limelight again. First, at the risk of being accused of ignoring an individual's right to due process, three cheers for the German scientific community's quick action in resolving the matter of publishing fraudulent research results without going through protracted legal wrangling. At the same time, I was somewhat concerned by the article on a conference attended by more than 200 people in Washington, D.C., to

Correction

- May 16, page 25: Installation cost for a Buss loop reactor for medium-scale hydrogenations would amount to $200,000 to $250,000, not the $750,000 implied. This cost would include positioning on foundations; piping, control, and electrical connections; and commissioning.

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Global Top 50 Chemical Producers Troubled By Low Prices, Slow Economies

■ ***Hoechst edges out BASF for top rank, Bayer garners fourth for strong German showing; overall, sales are down***

Patricia L. Layman, C&EN London

If 1992 was a bleak year for the international chemical industry, 1993 was not the restorative tonic the industry had hoped for. Chemical sales for the 50 largest international chemical producers were down 9% to $306 billion, and profitability continued to decline. However, the rate of that decline has begun to slow: the average chemical operating profit margin in 1993 was 7.2%, compared with 7.3% in 1992 (C&EN, July 26, 1993, page 29) and 7.5% in 1991. The average operating profit margin for 1990 was 9.9%, as the industry began slipping from the frothy heights of the late 1980s. The comparable average for 1989, the year C&EN began ranking the global Top 50 companies, was 14.4%.

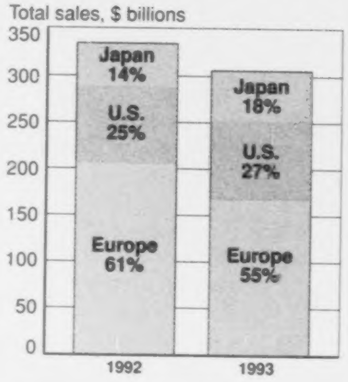
Moreover, last year's results reflected the effect of exchange-rate fluctuations on the industry even more than in 1992. For example, 11 Japanese companies rank among the Top 50 for 1993, one more than for 1992, and chemical sales of the top companies in Japan's chemical industry were up 15% from the year before. Most of that increase was attributable to the strong yen, for which the average exchange value relative to the dollar appreciated 14% in 1993 over 1992.

On the other hand, in recession-plagued Europe, currencies fell against the dollar—dropping from 6% in Germany and the Netherlands to 18% in the U.K. and 28% in Italy. Sales of the top European chemical companies totaled $168 billion in 1993, a decrease of 18% from a year earlier. These sales came from 24 companies, one less than the year before, and accounted for 55% of the global total, down from 61% in 1992. Nonetheless, three of the top four companies were German: Hoechst, which took first place this year, BASF, now number two, and Bayer, fourth. The U.S.'s DuPont took third place.

U.S. companies among the global Top 50 numbered 15, the same as last year. However, sales for the 15 as a percentage of the global total increased slightly, to 27% from 25%. Sales reached the same percentage level as in 1991, another year when the dollar was relatively strong.

Currency fluctuations were not the only factor in the overall drop in sales. Prices and volume of sales also played major roles, points out Alasdair Nisbet, chemicals analyst with London-based stock analysts UBS Ltd., as did divestitures of small, noncore corporate businesses. Sales for most companies were down, he says, in large part because of low product prices. That was particularly true for petrochemical and polymer producers—prices for products such as polyethylene, polyvinyl chloride, and polypropylene have been at "summer-sale" levels throughout the past year. And with the rising price of feedstocks, raw material costs are further squeezing petrochemical producers.

Europe's share of global Top 50 dropped in 1993



Only the yen increased against the dollar in '93

Currency	Change versus U.S. dollar 1992–93[a]
Japanese yen	+14%
Belgian franc	–8
British pound	–18
Dutch guilder	–6
French franc	–7
German mark	–6
Italian lira	–28
Norwegian crown	–14
Swiss franc	–5

[a] Average exchange rates each year.

As would be expected among the Top 50, there were shifts in the rankings; some 45 of the 50 companies changed places. Following British chemical giant ICI's midyear spin-off of its bioscience operations into a new company called Zeneca, ICI fell to fifth place from third, based on the pro forma results it reported for the full year. Two companies—Teijin of Japan and AlliedSignal of the U.S.—were added for 1993. Chevron, which appeared in the Top 50 for 1992, did not have sufficient sales to be included this year.

Consolidations and mergers announced or taking place late in 1993 will continue to shape the rankings. Nobel Industries of Sweden, because of its merger with Akzo of the Netherlands in late 1993, did not report year-end 1993 financial results and was removed from the ranking. Because the merger did not take place until November, C&EN's ranking shows only Akzo's results for 1993. Had the pro forma data provided by the new company been used, Akzo Nobel, as it is now called, would have ranked seventh among chemical producers worldwide.

For the most part, the major international chemical companies went on diets during 1993, selling off pieces here and there to managerial teams and other, usually smaller, companies. As UBS's Nisbet notes, "There has been a whole string of disposals through the industry, with few new consolidations." Slimmer giants mean, for C&EN's rankings based on 1993 sales, a smaller sales total.

Even the minimum level to be included in C&EN's global Top 50 was pared down slightly—AlliedSignal made it as 50th with chemical sales of $2.79 billion in 1993, compared with $2.81 billion for 50th-ranked Air Products & Chemicals in 1992. Barely missing inclusion in the 1993 ranking were such major companies as Saudi Basic Industries Corp. (SABIC) of Saudi Arabia; Chevron, Ashland, Praxair, and Phillips Petroleum of the U.S.; and Italy's Montedison, with its Montecatini chemical operations.

However, rising prices for their products will undoubtedly affect next year's listing of chemical producers. For example, SABIC credits a "gradual recovery of the global market" for improving its sales, currently extrapolated to exceed $3 billion for 1994.

The slimmer chemical sales also point to another facet of the international chemical industry: an increasing diversification away from basic or commodity chemicals. C&EN uses the same criteria in its global ranking as in its ranking of the 100 largest U.S. chemical producers (C&EN, May 9, page 13). Wherever possible, it excludes businesses such as pharmaceuticals, consumer products, and nonchemical operations such as equipment, metals, and energy.

For companies such as major oil producers Exxon, Shell, and Elf Aquitaine, breaking out chemical businesses for scrutiny is relatively straightforward. The same holds true for other nonchemical companies such as Unilever. At many other companies, however, reorganizations and restructurings are blurring the lines between classically "chemical" operations and, for example, biosciences—a category that might include anything from pharmaceuticals to diagnostics and chiral fine chemicals. ☐

Hoechst moves to top of global Top 50 chemical producers

Rank 1993	Rank 1992		Total sales ($ millions)	Chemical sales ($ millions)	Chemical sales as % of total sales	Chemical operating profits ($ millions)	Chemical operating profits as % of chemical sales
1	2	**Hoechst (Germany)**	$27,907	$16,682	60%	$155	0.9%
2	1	**BASF (Germany)**	26,135	16,082	62	417	2.6
3	5	**DuPont (U.S.)**	37,098	15,603	42	750	4.8
4	4	**Bayer (Germany)**	24,853	15,012	60	207	1.4
5	3	**ICI (U.K.)**	15,964	13,162	82	456	3.5
6	6	**Dow Chemical (U.S.)**	18,060	12,524	69	773	6.2
7	7	**Exxon (U.S.)**	111,211	10,024	9	411	4.1
8	8	**Shell (U.K., Netherlands)**	95,120	9,883	10	(614)[a]	nm
9	10	**Ciba (Switzerland)**	15,302	9,072	59	974	10.7
10	12	**Elf Aquitaine (France)**	37,045	8,675	23	(141)[a]	nm
11	13	**Asahi Chemical (Japan)[b,c]**	8,557	8,557	100	102	1.2
12	9	**Rhône-Poulenc (France)**	14,234	8,276	58	39	0.5
13	14	**Akzo Nobel (Netherlands)**	8,876	7,032	79	284	4.0
14	11	**ENI (Italy)**	34,244	6,762	20	244	3.6
15	17	**Mitsubishi Kasei (Japan)[b,c]**	6,363	6,363	100	29	0.5
16	20	**Sekusui Chemical (Japan)[b,c]**	6,280	6,280	100	102	1.6
17	16	**Veba (Germany)**	40,182	6,103	15	(127)[a]	nm
18	19	**Monsanto (U.S.)**	7,902	5,651	72	731	12.9
19	30	**Takeda Chemical (Japan)[b,c]**	5,131	5,131	100	339	6.6
20	27	**General Electric (U.S.)**	60,747	5,042	8	834	16.5
21	25	**Sumitomo Chemical (Japan)[b,c]**	4,984	4,984	100	(3)[a]	nm
22	22	**Henkel (Germany)**	8,404	4,924	59	235	4.8
23	29	**Toray Industries (Japan)[b,c]**	4,835	4,835	100	169	3.5
24	26	**Union Carbide (U.S.)**	4,640	4,640	100	354	7.6
25	28	**Norsk Hydro (Norway)**	8,794	4,463	51	96	2.2
26	15	**Solvay (Belgium)**	7,056	4,424	63	78	1.8
27	24	**DSM (Netherlands)**	4,503	4,409	98	(147)[a]	nm
28	21	**British Petroleum (U.K.)**	52,477	4,405	8	(102)[a]	nm
29	31	**Roche (Switzerland)**	9,672	4,336	45	na	nm
30	23	**BOC (U.K.)[d]**	4,858	4,312	89	587	13.6
31	35	**Dainippon Ink & Chemicals (Japan)[b,c]**	4,244	4,244	100	57	1.3
32	33	**Showa Denko (Japan)[b,c]**	4,227	4,227	100	(208)[a]	nm
33	18	**Air Liquide (France)**	5,367	4,132	77	na	nm
34	32	**Occidental Petroleum (U.S.)**	8,540	4,065	48	184	4.5
35	34	**Eastman Chemical (U.S.)**	3,903	3,903	100	476	12.2
36	37	**Amoco (U.S.)**	28,583	3,773	13	321	8.5
37	36	**Mobil (U.S.)**	64,235	3,533	6	25	0.7
38	40	**Unilever (U.K., Netherlands)**	41,836	3,514	8	353	10.0
39	42	**Sandoz (Switzerland)**	10,203	3,411	33	344	10.1
40	43	**Mitsui Toatsu Chemicals (Japan)[b,c]**	3,288	3,288	100	3	0.1
41	45	**Rohm and Haas (U.S.)**	3,269	3,269	100	267	8.2
42	38	**Total (France)**	23,936	3,251	14	254	7.8
43	44	**Arco Chemical (U.S.)**	3,192	3,192	100	425	13.3
44	41	**Courtaulds (U.K.)[b]**	2,996	2,995	100	264	8.8
45	48	**Mitsubishi Petrochemical (Japan)[b,c]**	2,984	2,984	100	(43)[a]	nm
46	50	**Air Products (U.S)**	3,328	2,906	87	417	14.3
47	39	**W. R. Grace (U.S.)**	4,408	2,895	66	392	13.5
48	47	**Degussa (Germany)[d]**	9,031	2,850	32	na	nm
49	—	**Teijin (Japan)[b,c]**	2,840	2,840	100	69	2.4
50	—	**AlliedSignal (U.S.)**	11,826	2,791	24	309	11.1

Note: Ranking based on chemical sales only. Excluded where possible are formulated products such as pharmaceuticals and cosmetics and specialty equipment, energy, and other nonchemical operations. **a** Operating loss. **b** Fiscal year ends March 31. **c** Net profits and net profit margin. **d** Fiscal year ends Sept. 30. **nm** = not meaningful. **na** = not available.

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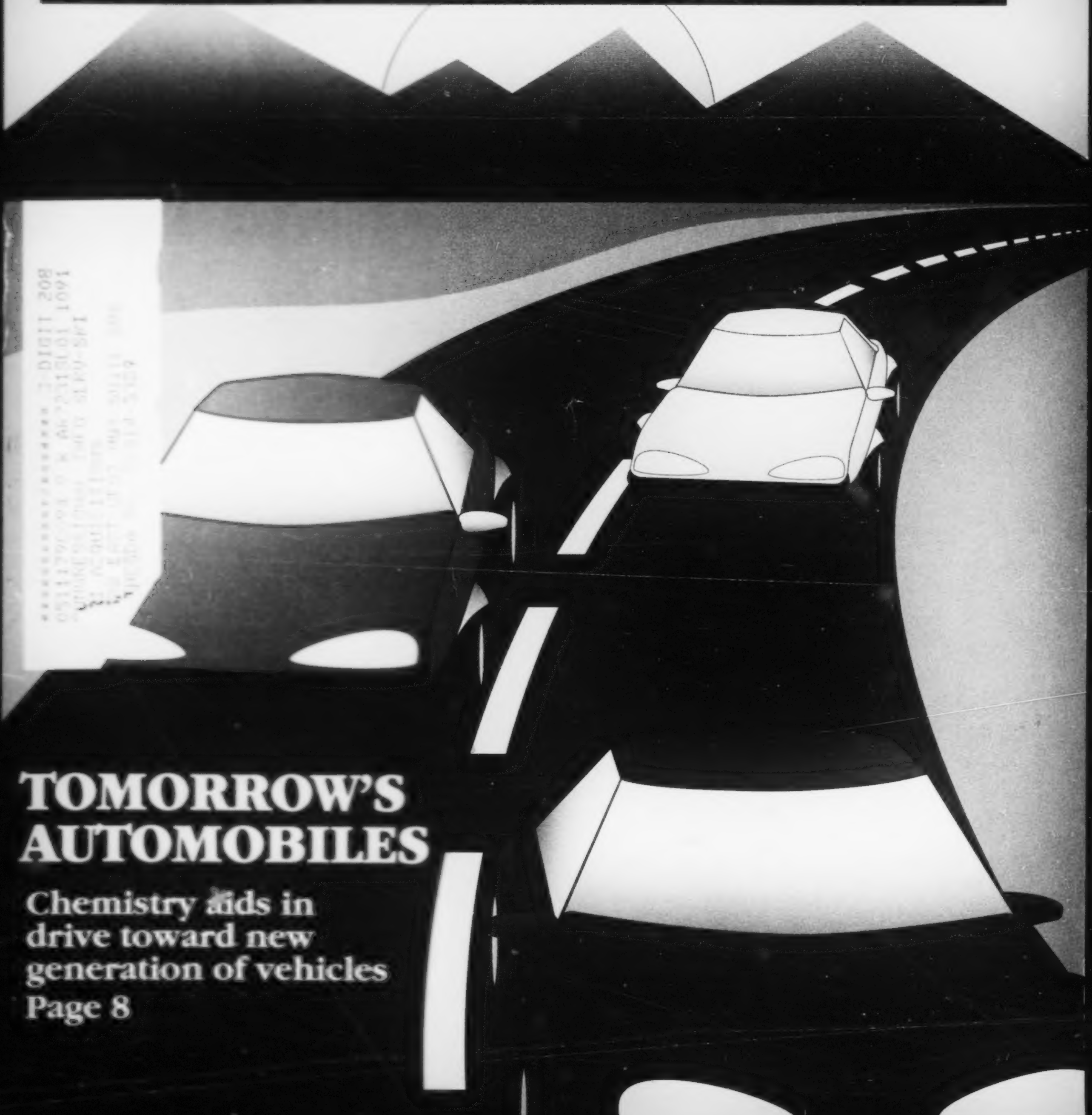
CHEMICAL & ENGINEERING NEWS

C&EN

AUGUST 1, 1994

U.S. QUEST FOR BETTER CHEMICAL ARMS DETECTION CONTINUES PAGE 26



TOMORROW'S AUTOMOBILES

Chemistry aids in drive toward new generation of vehicles
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C&EN
AUGUST 1, 1994

NEWS OF THE WEEK

- Two independent research groups discover extensive deposits of naturally occurring fullerenes in Canada and New Zealand. **Page 4**
- Chemical earnings are up again for the second quarter of 1994, helped by cost-cutting measures and productivity improvements undertaken by companies over the past few years. **Page 5**
- In a landmark case marking the first time the federal government has used the False Claims Act to pursue scientific research fraud, two U.S. universities will pay nearly $1.6 million to settle a case involving charges that a researcher falsified data. **Page 6**
- Presentations at an international conference suggest that the key to addressing global warming is preventing explosive growth of greenhouse gas emissions from developing nations. **Page 6**
- Genzyme has acquired BioSurface Technology and merged it into a new business unit focused on tissue repair and wound healing. **Page 7**
- During record-setting flight of almost 15 days in Earth orbit, space shuttle *Columbia* astronauts perform 81 microgravity experiments in materials and life sciences. **Page 7**

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BUSINESS

Chemical companies that added pharmaceutical businesses in the 1970s and 1980s consider the wisdom of keeping the capital-intensive units in view of today's business strategies. **Page 19**

Business Insights: Analysts watching the performance of biotechnology stocks fear that this year's spring plunge may not be followed by the usual turnaround. **Page 24**

GOVERNMENT

Detectors for chemical warfare agents worked well in the Persian Gulf War, although some alarms are still a puzzle; development of technology continues. **Page 26**

SCIENCE/TECHNOLOGY

Improved synthesis of taxol—and of taxol-like compounds that may show improved antitumor activity—from renewable starting materials is anticipated. **Page 34**

BOOKS

"The New Alchemists: Breaking Through the Barriers of High Pressure," by Robert Hazen, focuses on diamond synthesis and on the human side of high-level research. **Page 37**

ACS NEWS

Group of 1994 Petroleum Research Fund grants approved by ACS Board of Directors commits about one third of the $12.4 million grant budget authorized for 1994. **Page 39**

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Partnership for a New Generation of Vehicles, which involves the Big Three U.S. automakers and the federal government, looks to develop fuel-efficient, low-emissions vehicles during the next decade. Page 8

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LETTERS

Handheld chemical calculator

Contrary to Douglas E. Wedman's view (C&EN, June 20, page 4), the chemical calculator is not already here. The chemistry calculation capabilities of the HP48SX were well known to us and were cited in the application for the patent recently awarded to us. The uniqueness, as well as the usefulness of our chemical calculator derives from the use of the periodic table to perform the chemical calculations—a feature not found in the HP, nor in any other calculator of which I am aware.

The HP48SX, while having some powerful calculation capabilities, is not for everyone—especially beginning chemistry students—because of its steep learning curve. For example, to enter a chemical formula for the purpose of determining its formula weight, you must turn on the "alpha" mode to select the upper case first letter of the element symbol, then another key to get the lower case second letter. With CHEMiCALC, you just touch the element symbol on the periodic table. (The keys could be "mapped" out as part of the periodic table to do this if our program were incorporated into the HP.)

The potential effectiveness of my chemical calculator as a learning tool has been tested in some dozen high schools in the U.S. and Canada as part of a National Science Foundation Small Business Innovative Research (SBIR) program Phase I feasibility study. Unfortunately, because the Phase II proposal reviewers share many of Wedman's perceptions, the Phase II research designed to test out the effectiveness of a handheld chemical calculator in schools was not deemed significant enough for support.

Prototypes of the handheld chemical calculator/computer already under development or being considered for incorporation into calculators such as the HP, will be demonstrated at the American Chemical Society meeting in Washington, D.C., this August.

Bert Ramsay
Chemical Concepts Corp.
Ann Arbor, Mich.

The glowing future for the handheld chemical calculator, which was predicted by O. Bertrand Ramsay and David W. Brooks (C&EN, May 16, page 50), may eventually materialize, but initially—Gentlemen, temper your enthusiasm!

Ramsay makes the guarantee "that five years from now every chemist and chemistry student is going to be walking around with one of these . . . computers." Brooks suggests, "These devices are going to become so commonplace that students who don't have them are going to be at an extreme disadvantage." Perhaps they should recall Glenn Crosby's revelation about the state of affairs of computer use in secondary-level science education (C&EN, Sept. 21, 1992, page 28). Many of us still do not have ready access to a computer and future access is not imminent.

If one is teaching in a locale that operates within mandated fiscal parameters, the latest innovation from the "silicon tower" of research is certainly more than five years away from acquisition for the teacher's desk. One should probably not even consider acquisitions for the student's desk. For numbers of us, the maintenance of our science programs and a slow but trying advance are more important than a "hot" technological device.

The article notes that the handheld chemical calculator is intended primarily for high school students. Is the handheld chemical calculator a device that is truly needed? Have chemical calculations changed so much that our students need to be moved, during the next five years, away from their low-cost but effective periodic tables and simple calculators? Might students be in an equally secure calculating position if they acquired an old Keuffel & Esser No. 4160 from an estate sale, flea market, or garage sale?

The ACS "ChemCom" curriculum program has demonstrated Brooks' claim that one can get a foundation in chemistry without going through the old hoops. However, his assertion about students being at an extreme disadvantage without this device is, in reality, an announcement that the acquisition of the device will become a hoop to jump through. Do we need a new hoop? And, will the nature of general, introductory chemistry change so much in the next five years that this device will be the mandate Ramsay and Brooks suggest?

William C. Penker
Science Department
Neillsville High School
Neillsville, Wis.

Correction

- July 18, page 44: The color bar was labeled incorrectly in the image of the sea slug neuron. Colors represent concentrations of cyclic adenosine monophosphate [cAMP], not [Ca^{2+}].

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Chemical Industry Debates Merits Of Operating Pharmaceutical Units

■ ***Wave of acquisitions in 1970s and 1980s gives way to economic realities of focused, lower cost business strategies***

George Peaff,
C&EN Northeast News Bureau

During the end of the 1970s and throughout the 1980s, many companies entered into or acquired a business or businesses with value-added products in fields similar to their own as a hedge against the cyclic commodity products of their core businesses.

In the chemical industry, the trend was to buy into pharmaceuticals. Eastman Kodak, then owner of Eastman Chemical, bought Sterling Drug; Rhône-Poulenc put its drug operations together with Rorer Group; Monsanto obtained G. D. Searle; and Dow Chemical pieced together Marion Merrell Dow.

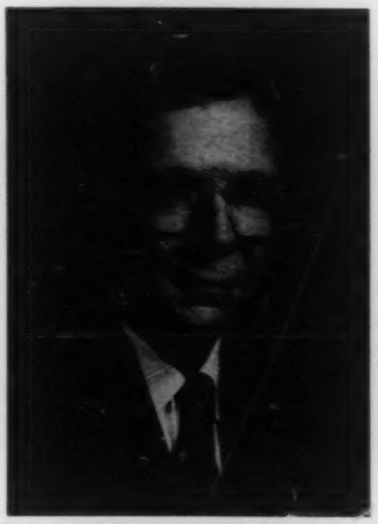
Each company had specific reasons to make the deals, but the common driving force was diversification to protect themselves from the cyclicality of their core operations, which were, and still are, determined by the rise and fall of economies, both local and global. U.S. companies seemed to be adopting the long-standing strategy of European business, especially Germany's major chemical producers.

Synergies exist between chemicals and pharmaceuticals: both are made through the manipulation of molecules, with chemicals being transformed to make other chemicals or pharmaceuticals. Pesticides, herbicides, and pharmaceuticals are highly evolved chemicals that have the ability to control biological activity. Before embarking into drug development, Dow Chemical and Monsanto had vast experience in pesticides and herbicides.

But the diversification craze in the 1970s and 1980s has been transformed in the 1990s into a trend toward focusing operations, cutting costs, and increasing productivity. Growth from offering new, value-added products and upward pricing has been replaced by growth through increasing market share, becoming the low-cost producer, and going overseas to new markets, often through joint ventures.

Producing and selling chemicals seemed to be at odds with producing and selling pharmaceuticals, despite the similarities. With the emergence of managed health care—cost containment—in the U.S., the ability to increase prices for pharmaceuticals has been drastically reduced, making it extremely difficult for companies to recoup their R&D investment.

According to one senior pharmaceutical executive, pharmaceuticals were a "natural marriage" for chemical makers such as Dow and Monsanto because the firms had an understanding of the technology and manufacturing process. And in the case of Eastman Chemical, at the time of Kodak's merger with Sterling, it claimed to have "had a portfolio of over 500,000 chemical entities that they wanted to screen for human [biological] activity" for potential products, says the pharmaceutical executive.



Mahoney: customers are more price conscious

J. Kent Riegel, president and general counsel for ICI Americas, the Wilmington, Del.-based U.S. subsidiary of U.K.'s ICI, describes the evolution of ICI in the 1960s and 1970s as a company having three segments—specialty chemicals, agricultural products, and pharmaceuticals—with agricultural products and drugs evolving out of ICI's old industrial divisions. Other European companies have long-standing operations in both chemicals and pharmaceuticals, including Bayer, BASF, Ciba-Geigy, Hoechst, Rhône-Poulenc, and Schering, to name a few.

However, from a financial perspective, a telling distinction is seen. "There is a big difference between chemicals and pharmaceuticals," says Paul Raman, vice president and chemical analyst at the New York City office of London-based investment bank S. G. Warburg. "Chemicals are driven by the economy; pharmaceuticals are not economically driven."

ICI became the first major chemical company to divest a major pharmaceutical business, completing the spin-off of Zeneca to its shareholders in June 1993. Economics as well as other factors played a major role in the divestiture. "We took a look at our portfolio in 1991 and 1992 and realized that through development, growth, and acquisition, we had, really, two separate cultures," comments ICI's Riegel, explaining the rationale behind the spin-off.

Biosciences—which are R&D intensive, have customer-specific products, and are focused on fine chemicals manufacturing—became part of Zeneca. And industrial chemicals became the new ICI, a large-volume and capital-intensive business with a heavy emphasis on process technology. "You try to manage these two very distinct cultures and you can't maximize their potential," continues Riegel. "And the other concern we had was that the stock market did not focus on the true value of the two components. 'Is this a chemical company with a large pharmaceutical business or is it a pharmaceuticals company with chemicals?' To give full value to [the opportunity to maximize the businesses' potential], we thought it made a lot more sense to just split them off into two pieces."

In the case of Kodak, its spin-off of Eastman Chemical to Kodak shareholders became only the first step toward a core business strategy. Its pending sale of Sterling Winthrop's prescription drug business to Sanofi S.A. moves the company further toward its goal of focusing on imaging businesses.

According to Charles Smith, vice president and director of communications at Kodak's health care segment, the company in the sixties and seventies had a strong position in health care with x-ray film products and equipment. By 1980, the company had commercialized blood analyzers and clinical diagnostics. As that business grew, by the mid-eighties, Kodak management made the decision to pursue an acquisition in the pharmaceutical field based on three areas in which the company had expertise: marketplace know-how in the health care industry, a commitment to fund and manage a large R&D program, and a deep understanding of chemistry and biology.

The health businesses that Kodak is divesting are very solid businesses, says Smith. The businesses are large, profitable, and have contributed solidly to Kodak. But, he continues, "Management is committed to succeeding in a major way in imaging, and in order to do so, it must apply the entire research base and management attention in this company on imaging. Even though [the health care units] are very attractive and well-run businesses generating good returns, they also require, going forward, significant investments."

Smith, who was a manager within Kodak's health care segment at the time of the acquisition, maintains that the merger was not a wrong move for Kodak. "It was absolutely the right thing to do at the time. And if you simply look at the financial reporting stream of the company since 1988, you will see that the health businesses made a very important and very significant contribution to the financial performance of the company."

The eventual divestment of Sterling and other health businesses, which accounted for 32% of Kodak's $16.4 billion in sales in 1993 (excluding sales from Eastman Chemical), will also help reduce its $7.1 billion debt load (as of March 31). Nearly half of this debt remains from the funding for the $5.1 billion acquisition of Sterling in February 1988.

However, others would dispute Kodak's commitment to Sterling from the beginning. "Kodak never should have gotten that company, because it wasn't prepared to invest the time, the energy, and the resources to make it successful," says the senior pharmaceutical executive. "It wasn't interested in understanding the business. [Kodak] thought it would just buy [Sterling, which,] under its own volition, . . . would somehow become successful."

Although becoming low-cost producers through cost cutting and productivity initiatives has become a driving force at almost every company regardless of location, U.S. companies have taken the lead in most industries. But as the costs associated with U.S. health care remain hotly debated, Dow and Monsanto appear to be under pressure from their large, institutional investors and Wall Street investment banks to shed their drug segments to a company focused on pharmaceuticals.

Monsanto commenced its tender offer for Searle in 1985, paying $2.7 billion for the business. In 1993, Searle contributed $1.5 billion of Monsanto's $7.9 billion in total sales. Dow Chemical acquired 38.9% of Marion Laboratories for $2.2 billion in August 1989 and combined Marion into its Merrell Dow drug subsidiary in December 1989, forming Marion Merrell Dow (MMD). Dow subsequently has increased its stake in MMD from an initial two thirds to a 72% shareholding now. In 1993, MMD posted sales of $2.8 billion, a 15% decline from 1992.

Warburg's Raman believes that Dow's and Monsanto's drug operations "are worth more to someone who's in the [pharmaceutical] business." He estimates the divestment value per share for MMD and G. D. Searle would be $25 per share, based on the four times book value and two and a half times sales value achieved in the Roche Group's tender offer for Syntex (C&EN, May 9, page 4). As of July 21, MMD's shares were trading at $20 on the New York Stock Exchange.

Raman gives several reasons why both MMD and Searle have not justified their purchase by their parents: key drugs have come off patent, the scale required for the R&D commitment for pharmaceuticals has not been achieved, the R&D pipeline for promising drugs is virtually empty, and no global infrastructure has been installed.

In the case of Dow, it created MMD to market the antihistamine Seldane, taking advantage of Marion's large sales force, says Raman. But with that drug now off patent, Dow should focus on chemicals. As for Monsanto's Searle, its key cardiac drug, Calan, "has already happened," he says. "Under the ideal plan, Monsanto would take biotechnology and revolutionize [agriculture] and drugs." But whereas the NutraSweet portion of Searle (now run independently) has paid for itself, the entire Searle acquisition has not, maintains Raman.

Five U.S. drug firms were formed in past 10 years by major chemical producers

$ Millions	Sales, 1993	Operating income, 1993	Parent/% ownership
Hoechst Celanese[a]	$ 757	$ 17	Hoechst A.G./100%
Marion Merrell Dow	2,818	439[b]	Dow Chemical/72%
Rhône-Poulenc Rorer	4,019	675[c]	Rhône-Poulenc S.A./68%
G. D. Searle	1,546	–13	Monsanto/100%
Sterling Winthrop[d]	1,920	na	Eastman Kodak/ 100%[e]

[a] U.S. sales and operating income for all the company's life science activities, including Hoechst Roussel's pharmaceuticals, Hoechst Celanese's crop protection and animal health products, and 51% stake in Copley Pharmaceutical, acquired November 1993. [b] Reflects $180 million restructuring charge. [c] Reflects $194 million restructuring charge and $105 million gain from litigation settlement. [d] Prescription pharmaceutical sales only. [e] Sale pending to Sanofi S.A. **na** = not available.

Monsanto's chairman and chief executive officer, Richard J. Mahoney, addressing shareholders in the company's 1993 annual report, says Monsanto is looking for Searle "to pay its own way" and to meet corporate targets, including the company's 20% return on equity goal. To do so, Monsanto will seek alliances with others to achieve cost savings, gain products, and achieve a larger pharmaceutical market presence.

The company's original strategy behind acquiring a pharmaceuticals operation has not changed, according to Mahoney in a recent interview with C&EN. It was—and is—based on the company's investment in biotechnology for pharmaceuticals, agriculture, and animal sciences beginning in the late seventies as Monsanto continued to move away from highly cyclical and capital-intensive commodity petrochemicals and into higher value chemicals.

The company also saw and still sees pharmaceuticals as "one of the higher value opportunities to upgrade R&D," Mahoney says. "We thought that our research base was biological sciences, which was growing stronger and stronger [and] could be capitalized on in pharmaceuticals. We continue to work through the biological sciences. We haven't had as much come out of research as we would have liked at Searle, but the pipeline now is quite strong and we're very optimistic."

What has changed in the pharmaceutical marketplace, he says, is that the opportunity to introduce a product similar to one already on the market, but with no economic advantage, has disappeared—cost-performance benefits must be there. "Any industrial chemical company is brought up that way," Mahoney states. "The pharmaceutical industry was not. It was brought up on performance: What will [a product] do to improve health? What are the side effects? What level of risk will you take?" In the current marketplace, customers are much more price conscious, "but still willing to pay for innovative products."

As outlined by Mahoney, Monsanto is committed to Searle. "Searle has plenty of capability in R&D in the fields we've chosen. It has very good marketing strength in the U.S. and in a number of countries, but not in all the major countries in the world. We've got a business that can be an attractive part of the company, we're running it as hard and as fast as we can, and we're trying to find alliances to make it even more important. If we don't find selective alliances, I think we are capable of developing as is with smaller alliances, the kind we've been doing right along."

Patterson: generics are a cost-driven business

Although Dow declined to comment on its plans for MMD, in late June, in response to speculation in the financial press, Dow issued a statement saying that it would consider the sale of its stake in MMD, but nothing was pending and the drug company was not being shopped around.

But Warburg's Raman says MMD and Searle would be attractive to pharmaceutical makers—especially European companies—looking to establish or increase their presence in the U.S. Other Wall Street analysts seem to agree with his assessment.

"[They] can't survive as independents," says Barbara A. Ryan, pharmaceutical analyst at the New York City office of Baltimore-based investment bank Alex. Brown & Sons. She foresees both MMD and Searle being sold. Both have some degree of scale, but market share in the managed care arena is necessary, she says, and, with infrastructure and fixed costs still high, both companies are losing to generic competition. She sees little motivation for a U.S. concern to be interested in the two companies, but European companies already with a share of the world market and greater financial resources than their U.S. counterparts would be interested.

Other factors affect the success or failure of combining companies. David Saks, vice president and pharmaceutical analyst at New York City-based investment bank Gruntal & Co., takes the view that the "odds are worse than 50-50" that big mergers will work because of the clash in culture, infrastructure, and industry focus. "Odds don't favor making an acquisition and swallowing it up," he comments, saying small, specialty, and niche mergers have a better chance to succeed. As an example, he cites the different cultures at Kodak and Sterling: Kodak wanted volumes in the millions of gallons range, but Sterling was looking at volumes in pints.

And as described by the senior pharmaceutical executive: "The chemical guys didn't get what they thought they were going to get; they paid big prices and are frustrated now by their inability to get the returns off those investments that they made. It's entirely different for the European guys coming into this market today, knowing what the market presents. [They] already have research capability outside the U.S."

But as some parent firms seek to shed their pharmaceutical segments and smaller drug companies look for ways to grow, other companies, particularly the major European firms, are looking to add to their operations, especially as the dollar keeps declining against the other major currencies, the German mark and Japanese yen primarily. The best example is Switzerland-based Roche Group, the owners of Hoffmann-LaRoche, which is in the tender offer process to acquire California-based Syntex for $5.3 billion.

Hoechst Celanese, the U.S. unit of Germany-based Hoechst A.G., having already decided to expand its presence in the U.S. pharmaceutical market, acquired a 51% stake in Copley Pharmaceutical, a generic drugmaker, for $546 million in November 1993. In 1993, Hoechst Celanese ended the year with sales of $6.9 billion, with its life sciences segment, including pharmaceuticals, contributing $757 million in sales.

Joseph H. Patterson, Hoechst Celanese's deputy chairman, diagrams the company's entrance into the generic side of the pharmaceutical business. Similarly, MMD entered further into

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generics in June 1993 with the acquisition of the generic drug business of the Rugby-Darby Group. In the 1970s, he says, pharmaceuticals were "a very fertile research field and the total market expanded because there were new compounds for therapeutic areas that had [no treatments available]. You're now down to a very small number of therapeutic areas that don't have [at least one treatment].

"Generics are a natural movement of that 1970s rich, fertile area to the next stage," he continues. Because patents run out, "generics come in and fill the bill." Patterson cites that between now and 1997, "a significant number" of compounds will be coming off patent and going generic, with the generic industry likely growing 12 to 14% over that time frame and the "branded industry" remaining flat.

Generics will be a cost-driven business. "There is no research arm to this, there's a development arm, a formulation arm," says Patterson. In a mature generic drug market, like the U.K. or Germany, generics behave like commodity products. "You have a small number of players, two or three [firms that] have large shares and others have niches," says Patterson.

For Hoechst Celanese, the Copley stake will help to increase its share in the U.S. pharmaceutical market and more closely match its parent's fourth largest ranking in the worldwide drug market, says Patterson. "We don't have a position in the U.S. that reflects our worldwide strength. We believe because of the position of the generic business, and its impending consolidation and growth, that we can play a much larger role in generics than we have been able to play thus far in branded pharmaceuticals here. Furthermore, we've got some significant strengths in chemicals that allow us to make bulk active [ingredients]."

Patterson sums up a prevailing belief about the changing nature of the pharmaceutical industry. "It is not easy to either build or manage the expertise that is required to be successful in the pharmaceutical business today, because discovery is one piece of it—but development has become a significantly bigger piece."

Rhône-Poulenc's position in pharmaceuticals recently came under scrutiny because of the misinterpretation of a recent filing with the Securities & Ex-

Neff: firms need long-term thinking

change Commission (SEC). Rhône-Poulenc Rorer, the U.S. pharmaceutical unit owned 68% by French-based Rhône-Poulenc, saw its stock take a roller-coaster ride in June. In the early part of the month, investors drove the stock price up 10%, thinking Rhône-Poulenc was going to raise its stake in Rhône-Poulenc Rorer. Days later, after Rhône-Poulenc said it had no immediate intention to raise its Rhône-Poulenc Rorer stake, investors sold off the previous gain.

Rhône-Poulenc combined its pharmaceutical business with U.S.-based Rorer Group to form Rhône-Poulenc Rorer in July 1990. The recent SEC filing and the actions surrounding it involve the merger agreement between Rhône-Poulenc and Rhône-Poulenc Rorer's minority shareholders. In the filing, Rhône-Poulenc revealed it had the option to acquire more shares in Rhône-Poulenc Rorer—despite a seven-year standstill agreement it pledged to keep as part of the merger deal—if it gained approval from two of the three outside directors on Rhône-Poulenc Rorer's board.

The previously undisclosed option led to speculation that Rhône-Poulenc was considering a change in ownership position at Rhône-Poulenc Rorer. But Rhône-Poulenc has stressed that the amendment as part of the filing gives the company "normal flexibility in day-to-day management."

"We want to be in chemicals, and we want to be in life sciences, and we define life sciences as pharmaceuticals, animal health and nutrition, and agricultural chemicals," says Peter J. Neff, president and chief executive officer of Rhône-Poulenc Inc., the Princeton, N.J.-based U.S. subsidiary of Rhône-Poulenc. He says a similar strategy has driven all of Rhône-Poulenc's acquisitions over the years—"enhancing and rebalancing the geographic presence in different parts of the world."

Synergies exist between the different businesses in Rhône-Poulenc, according to Neff. "It pays to be in chemistry, [to] maintain those core skills of chemical synthesis and process chemistry married with the pharmaceutical market. As we go on in time, we think that some of the genetic manipulation skills that we have now in pharmaceuticals will translate back to the chemical industry."

Rhône-Poulenc intends to be 50% in chemicals and 50% in life sciences, states Neff. But the R&D commitment to life sciences—13 to 14% of sales—exceeds that to chemicals—4 to 5% of sales—because "the lifeblood of the life sciences industry is corporate research coming up with new products."

Neff points out that companies must look to the long term, not short term. "Many leaders of companies get caught up in the analysts' expectations of what a company should be, and by definition, that drives short-term thinking because the analysts are interested in quarterly results. [A company] succeeds or fails based on maintaining a robust strategy and having the skills to implement that strategy over a long period of time."

Companies may have lost sight of long-term goals in the 1980s, says Neff, but have returned to long-term thinking in the 1990s. And who owns stock in a company may also be a factor. "The stock ownership in Europe tends to be much more by large banks and large insurance companies, which by nature have a long-term view. In the U.S., you have mutual fund companies and individual investors who tend to be more short-term focused." ☐

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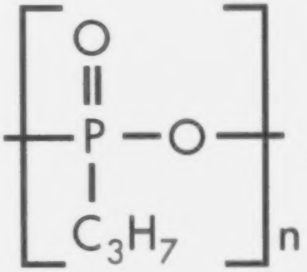

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Group Of 1994 Petroleum Research Fund Grants Approved by Board

The ACS Board of Directors has approved 137 new or continuing ACS-Petroleum Research Fund (PRF) grants for fundamental research or scientific education, plus 29 supplements to existing grants for Summer Research Fellowships to benefit faculty from four-year colleges. These grants, committing $4,509,689 of the $12.4 million authorized for 1994, were recommended from the 544 proposals considered by the PRF Advisory Board.

The 1994 PRF grant budget has been reduced in response to the continuing lower yield from investments. The low success rate of just over 20% for Type AC proposals is not satisfactory for applicants nor for the PRF Advisory Board. Further reduction in the 1995 PRF grant budget is anticipated.

Information and application materials may be obtained from the Petroleum Research Fund, American Chemical Society, 1155—16th St., N.W., Washington, D.C. 20036; phone (202) 872-4481.

ACS-PRF Grants for Fundamental Research in the Petroleum Field (Type AC)

Stephen P. Altaner, U of Illinois, Urbana-Champaign. Mechanism of Smectite Illitization in Bentonite: Analysis of Mixed-Layer Illite/Smectite in Cretaceous and Devonian K-Bentonites. $50,000

Hans G. Ave Lallemant, Rice U. Geochronologic Constraints for the Serrana del Interior Foreland Fold and Thrust Belt, North-Central Venezuela. $50,000

Anna C. Balazs, U of Pittsburgh. Determining the Behavior of Copolymers at Penetrable Interfaces through Modeling and Simulation. $37,500

Jayanth R. Banavar, Pennsylvania State U. Phase Transitions in Porous Media. $50,000

Robert A. Beaudet, U of Southern California. Rovibrational Spectroscopy of Open-Shell van der Waals Molecules. $50,000

Ali Borhan, Pennsylvania State U. Motion of Drops through Periodically Corrugated Capillaries at Low Reynolds Numbers. $50,000

William J. Brittain, U of Akron. Synthesis of NLO Polycarbonates via the Ring-Opening Polymerization of Macrocyclic Prepolymers. $50,000

David S. Chapman, U of Utah. Relationships between Tectonics, Temperature, and Hydrocarbon Generation and Migration in the Taranaki Basin, New Zealand: A Comprehensive and Evolving Study. $47,636

Paulette Clancy, Cornell U. Early Stages of Crystal Nucleation and Growth in the Processing of Metals. $50,000

Edward L. Clennan, U of Wyoming. Reactions of Singlet Oxygen with Sulfenyl Derivatives. $50,000

Jeffery L. Coffer, Texas Christian U. Correlating Surface Chemistry and Structure in Porous Silicon. $50,000

David F. Coker, Boston U. Nonadiabatic Reaction Dynamics in Solution. $50,000

Joshua M. Deutsch, U of California, Santa Cruz. Design of Copolymeric Materials. $50,000

William R. Dolbier Jr., U of Florida. Torquoelectronic Effects in Pericyclic Reactions. $40,000

Luis Echegoyen, U of Miami. Fullerenes, Fulleroids, and Fullerides: Electrochemistry, ESR, and Supramolecular Complexation. $50,000

M. Samy El-Shall, Virginia Commonwealth U. Cluster Polymerization Catalyzed by Gas-Phase Metal Cations. $50,000

John E. Ellis, U of Minnesota. Syntheses and Chemistry of Anionic Bis(Arene) Metal Complexes. $50,000

Thomas W. Engel, U of Washington. Atomic-Level Structure of TiO_2 Determined with UHV, STM, and AFM. $50,000

Frank G. Ethridge, Stanley A. Schumm, Colorado State U. 3-D Facies Architecture of the Aggrading, Braided Niobrara River, a Modern Analog for Braided Fluvial Deposits that Host Significant Hydrocarbon Resources. $50,000

John W. Faller, Yale U. Asymmetric Catalysis with Chiral Transition-Metal Organometallics. $50,000

Erik J. Fernandez, U of Virginia. Magnetic Resonance Imaging Analysis of Viscous Fingering. $50,000

John H. Frederick, U of Nevada, Reno. Molecular Gyroscopes: A Study of the Interactions between Methyl Rotors and Molecular Rotation. $50,000

Robert E. Gawley, U of Miami. Properties and Synthetic Applications of α-Amino and α-Alkoxy Organolithiums. $50,000

Harry W. Gibson, Virginia Polytechnic Institute & State U. New Approaches to Polymeric Ketones. $37,500

Andrew Hajash Jr., Texas A&M U. Porosity Modification in Sandstone Reservoirs: Effects of Organic Acids. $47,940

Luke Hanley, U of Illinois, Chicago. Growth of Thin Film Plasma Polymers by Molecular Ion Beam Epitaxy. $50,000

Timothy P. Hanusa, Vanderbilt U. Organometallic Compounds of the Alkaline-Earth Metals as Reagents in Synthetic and Materials Chemistry. $50,000

Joseph A. Heppert, U of Kansas. Transition-Metal Complexes Containing Highly Tunable Hydrogen Bonds: Reactivity and Applications in Molecular Design. $50,000

John F. Hershberger, North Dakota State U. Infrared Laser Studies of Nitrogen Combustion Chemistry. $50,000

David R. Heskett, U of Rhode Island. Structure of Molecules on Metal Surfaces Investigated with X-ray Standing Waves. $50,000

Steven Holdcroft, Simon Fraser U. Photoimaging of Novel Photolabile Electronically Conducting Polymers. $50,000

Zhibing Hu, U of North Texas. Volume Phase Transition and the Mechanical Properties of Polymer Gels. $50,000

Ian E. Hutcheon, U of Calgary. Origin of H_2S in Sedimentary Fluids and Its Effect on the Diagenesis of Clastic and Carbonate Rocks. $50,000

James T. Hynes, U of Colorado. Theoretical Studies of the Energetics and Dynamics of Acid Ionization at Ice-Air and Water-Air Interfaces. $50,000

Bart Kahr, Purdue U. Desymmetrization Strategies in Mixed Crystals of Simple Isomorphous Salts. $50,000

Miriam Kastner, U of California, San Diego. Marine Barite: A Potential Recorder of Oceanic Productivity. $50,000

Kerry R. Kelts, U of Minnesota. Models for Carbon and Oxygen Isotope Trends of Holocene Carbonate Lacustrine Sequences from the Northern Great Plains, U.S.A. $49,980

Paul D. Kleiber, U of Iowa. Chemical Dynamics of Metal Ion-Molecule "Half-Collisions." $50,000

Stephen J. Klippenstein, Case Western Reserve U. Theoretical Studies of Organometallic Reaction Dynamics. $50,000

Jacqueline Krim, Northeastern U. Dynamic Scaling of Self-Affine Fractal Surfaces. $50,000

Stephen Lee, U of Michigan. Predicting Intermetallic Structures and Superstructures. $50,000

Lance L. Lobban, U of Oklahoma. Catalysis by Surfactant Aggregates Adsorbed on High-Surface-Area Supports. $50,000

Stephen J. Loeb, U of Windsor. Molecular Recognition via Simultaneous First- and Second-Sphere Coordination. $50,000

Fred T. Mackenzie, U of Hawaii, Manoa. Dolomite Precipitation Kinetics: The Role of Temperature and Solution Composition. $50,000

James M. Mayer, U of Washington. Oxidation of Alkanes and Arylalkanes by Transition-Metal Oxo Complexes. $50,000

Roberto D. Merlin, U of Michigan. Raman Scattering by Spin-Pair Excitations in Layered Antiferromagnets at High Pressures. $49,965

Jeffrey S. Moore, U of Illinois, Urbana-Champaign. Modular Building Blocks with Conformational Bistability. $50,000

Joseph M. O'Connor, U of California, San Diego. Diazocarbonyl Reactivity toward Alkyne Complexes: Metallacyclobutenes as Reactive Intermediates. $50,000

Robert G. Parr, U of North Carolina, Chapel Hill. Density Functional Theory of the Maximum Hardness Principle, the HSAB Principle, and Aspects of Catalysis. $50,000

Daniel J. Pasto, U of Notre Dame. Study of the Regio- and Stereoselectivity of the Addition of Reactive Intermediates to Chiral Allenes. $50,000

Mark A. Person, Hans-Olaf Pfannkuch, U of Minnesota. Geostatistical Models of Long-Range Oil Migration: An Example from the Paris Basin, France. $49,953

Peter Pfeifer, U of Missouri, Columbia. Wetting Transitions on Fractal Surfaces. $50,000

Gary J. Pielak, U of North Carolina, Chapel Hill. Osmolytes and Protein Amide Proton Exchange. $40,000

Daniel H. Rothman, Massachusetts Institute of Technology. Discrete Three-Dimensional Multiphase Fluids for Efficient Numerical Investigation of Effective Transport Properties. $50,000

David S. Rumschitzki, City U of New York, City C. Effect of Pore Corrugation on Liquid-Liquid Displacements with Application to Oil Recovery. $50,000

Zoltan A. Schelly, U of Texas, Arlington. Electroporation of Unilamellar Surfactant Vesicles. $50,000

Richard D. Sheardy, Seton Hall U. Thermodynamic Studies of DNA Oligomers with Unusual Structures. $50,000

Robert S. Sheridan, U of Nevada, Reno. Photochemical Generation of Low-Spin Carbenes, Bis-Carbenes, and Biradicals. $50,000

Everett L. Shock, Washington U. Co-Transport of Metals and Organic Compounds during Diagenesis and Hydrothermal Processes: N-, P-, and S-Bearing Ligands. $50,000

Rudy L. Slingerland, Pennsylvania State U. Significance of Downstream Fining in Ancient Fluvial Deposits. $47,215

Gary J. Snyder, U of Chicago. Study of the Thermochemistry of Organic Transients by Photoacoustic Calorimetry. $50,000

Julian Talbot, Purdue U. Transport of Molecular Fluids in Porous Media. $50,000

Christian P. Whitman, U of Texas, Austin, C of Pharmacy. Mechanistic Studies of Isomerases Involved in the Microbial Degradation of Aromatic Hydrocarbons. $50,000

ACS-PRF Grants for Fundamental Research in the Petroleum Field (Type B)

James C. Barborak, U of North Carolina, Greensboro. Design of New Alkene/Carbon Monoxide Copolymer Architectures Using Palladium Catalysts. $25,000

Ronald J. Duchovic, Indiana U-Purdue U, Fort Wayne. Molecular Dynamics: Chemical Kinetics and Potential Energy Surfaces. $25,000

Larry G. French, Saint Lawrence U. Temporary Tether Diels-Alder Reactions Relying on Boron-Based Weak Links: Exploiting Removable Connecting Chains To Afford Intermolecular Diels-Alder Products Intramolecularly. $25,000

Jennifer Z. Gillies, Siena C. Spectral Characterizations of Transient Organosulfur Compounds and van der Waals Complexes by Pulsed Beam Supersonic Jet Fourier-Transform Microwave Spectroscopic Techniques. $25,000

Thomas H. Giordano, New Mexico State U. Experimental and Theoretical Studies of Calcium and Magnesium Organic Complexing under Hydrothermal Conditions. $25,000

David E. Hansen, Amherst C. Use of Torsionally Distorted Dipeptide Mimics To Elicit Antibody Proteases. $25,000

Mariusz Kozik, Canisius C. Carbon Dioxide Activation by Heteropoly Complexes in Nonpolar Solvents. $25,000

Jane V. Z. Krevor, San Francisco State U. Synthesis, Electrochemistry, and Nuclear Magnetic Resonance Spectroscopy of a New Series of Heterobimetallic Complexes. $25,000

Chriss E. McDonald, Lycoming C. Reductive Cleavage of Vicinal Monoprotected Diols. $25,000

Keith H. Meldahl, Oberlin C. Taphonomy and Time-Averaging of Molluscan Assemblages in a Rift Basin: Tectonic and Paleoecologic Implications. $25,000

Dorothy J. Merritts, Franklin & Marshall C. Late Quaternary Crustal Deformation and Surface Uplift in the Banda Arc Collision Zone, Indonesia. $25,000

Donald P. Poe, U of Minnesota, Duluth. Efficiency in Supercritical Fluid Chromatography. $25,000

John M. Risley, U of North Carolina, Charlotte. Synthesis of Substrate Analogs To Obtain an Energetic Fingerprint of the Active Site of Aspartylglucosaminidases. $25,000

Thomas J. Smith, Kalamazoo C. Comparative Electron-Transfer Studies on Vanadium and Molybdenum Complexes. $25,000

Leonard J. Soltzberg, Simmons C. Mechanism of Crystal Dendrite Formation. $25,000

Kenneth L. Stevenson, Indiana U-Purdue U, Fort Wayne. Exciplexes in the Photolysis of Inorganic Coordination Complexes. $25,000

Nivaldo J. Tro, Westmont C. Adlayer Structure and Desorption Kinetics of Alkanes Adsorbed on Al_2O_3(0001). $25,000

Daniel R. Willey, Allegheny C. Equilibrium Pressure Broadening and Energy Transfer Studies, 2–100 K. $25,000

Viktor V. Zhdankin, U of Minnesota, Duluth. Preparation and Study of Organic Derivatives of Xenon(II). $25,000

ACS-PRF Grants for Fundamental Research in the Petroleum Field (Type G)

Awarded to faculty in Ph.D.-granting departments

Jonathan P. D. Abbatt, U of Chicago. Laboratory Studies of OH, HO_2, and ClO Heterogeneous Chemistry on Sulfuric Acid Surfaces. $20,000

Roderick W. Bates, U of North Texas. Transition-Metal-Mediated Cyclization Reactions. $20,000

Valerie Daggett, U of Washington. Molecular Dynamics Simulations of Ubiquitin in Methanol. $20,000

John R. Dorgan, Colorado School of Mines. Grafting Polymer Chains to Solid Surfaces. $20,000

Judith L. Eglin, Mississippi State U. Oxidative Addition of Chlorinated Hydrocarbons to Quadruply Bonded Ditungsten Complexes. $20,000

Gregory C. Fu, Massachusetts Institute of Technology. Directed, Metal-Catalyzed Reactions. $20,000

Daniel K. Holm, Kent State U. Assessing Vertical Axis Rotations in Large-Magnitude Extensional Regimes: A Case Study of the Black Mountains, Death Valley Extended Terrain, California. $20,000

William S. Jenks, Iowa State U. Photochemistry of Aromatic Sulfoxides. $20,000

Deborah A. Kallick, U of Minnesota. Structure and Dynamics of a Peptide-Lipid Complex Using Nuclear Magnetic Resonance Spectroscopy. $20,000

Brian B. Laird, U of Kansas. Localized Vibrations and Spectral Diffusion in Glasses. $20,000

Cynthia K. Larive, U of Kansas. Probing the Relationship between Structure, Aggregation, and Conformation in Model Peptides. $20,000

James W. Leahy, U of California, Berkeley. Novel Electron-Deficient Systems: Preparation of Unique Nonclassical Organic Cations and Radicals. $20,000

Nancy E. Levinger, Colorado State U. Probing the Role of Vibrational Relaxation on Chemical Reaction Dynamics. $20,000

Mian Liu, U of Missouri, Columbia. Thermal-Rheological Modeling of Crustal Shortening and Extension. $20,000

Jianping Lu, U of North Carolina, Chapel Hill. Novel Properties of Fullerenes and Related Materials. $20,000

En Ma, Louisiana State U. Self-Propagating Explosive Chemical Reactions in Submicron Multilayer Thin Films. $20,000

George C. McBane, Ohio State U. State-to-State Dynamics of the Reactions of $O(^3P)$ with Acetylene, Formaldehyde, and Methane. $20,000

Robin L. McCarley, Louisiana State U. Probing Metal-Adsorbate Interactions with Scanning Probe Microscopy. $20,000

Fernando J. Muzzio, Rutgers, State U of New Jersey. Using Mixing To Enhance Selectivity and Minimize Waste in Reactive Systems. $20,000

David T. Pierce, U of North Dakota. Structurally Perturbed Electron Transfer in Pendent-Macrocycle Complexes. $20,000

Bradley B. Sageman, Northwestern U. Investigation of Skeletal Limestone Deposits in the Greenhorn Cyclothem: Paleoenvironmental Implications and Sequence Stratigraphy. $20,000

T. Daniel P. Stack, Stanford U. Sterically Encumbered Chalcogenide Ligands: Hydrogenase Models and Beyond. $20,000

Ya-Ping Sun, Clemson U. Photophysics and Photochemistry in Supercritical Fluids and Mixtures. $20,000

Sally J. Sutton, Colorado State U. Altered Zircons in Modern Sands as a Tool for Interpreting Ancient Sandstones. $20,000

Iwao Teraoka, Polytechnic U. High-Yield Fractionation of Polymers by Nanoscale Porous Materials. $20,000

Joseph P. Woods, U of Nebraska, Lincoln. Magnetization and Chemisorption on Bimetallic Ferromagnetic Surfaces. $20,000

Ziling B. Xue, U of Tennessee. New Molecular Routes to Early-Transition-Metal Silicides. $20,000

Gordon T. Yee, U of Colorado. Design, Synthesis, and Characterization of Novel Magnetic Molecular Solids. $20,000

Arun Yethiraj, U of Wisconsin, Madison. Polymer Melts and Blends: Bulk Phase Transitions and Behavior Near Surfaces. $20,000

Lei Zhu, State U of New York, Albany. Cavity Ring-Down Optical Spectroscopy for Studying Atmospheric Carbonyl Reactions. $20,000

Awarded to faculty in non-Ph.D.-granting departments

Barbara A. Bansenauer, U of Wisconsin, Eau Claire. Hydrocarbon Oxidation over Platinum and Palladium: Large Oxygen Coverages. $20,000

Darrell S. Kaufman, Utah State U. Amino Acid Racemization in the High-Molecular-Weight Fraction of Biogenic Carbonate: Chronostratigraphic Applications. $20,000

Elise G. Megehee, Barnard C. New Luminescent Complexes of Rhodium(III) and Iridium(III). $20,000

Julie T. Millard, Colby C. Mechanism of the Carcinogenicity of Epoxide Metabolites. $20,000

Miguel O. Mitchell, Albright C. Total Enantioselective Synthesis of Dihydroflustramine C. $20,000

Christopher J. Pursell, Trinity U. Photo-Induced Chemical Reactions on Amorphous Solid Surfaces with Emphasis on Systems of Atmospheric Interests. $20,000

Silvia E. Ronco, U of South Dakota. Photochemistry of Macrocyclic Copper Compounds Bound to Polyelectrolytes: Photogeneration of Copper Complexes in Unusual Oxidation States. $20,000

ACS-PRF Grants for Fundamental Research in the Petroleum Field (Type SE)

James E. Bauer, Ronald Benner, on behalf of the ACS Divisions of Geochemistry Inc. and of Petroleum Chemistry Inc. Measurement and Reactivity of Organic Materials in Natural Waters at the 207th ACS national meeting, San Diego, March 1994. $2,000

Brian E. Bent, on behalf of the ACS Division of Colloid & Surface Chemistry. Frontiers of Surface Reactivity at the 207th ACS national meeting, San Diego, March 1994. $1,000

Laurie J. Butler, on behalf of the ACS Division of Physical Chemistry. Nonadiabatic Dynamics at the 208th ACS national meeting, Washington, D.C., August 1994. $2,000

Martin Caffrey, on behalf of the ACS Division of Carbohydrate Chemistry. Carbohydrate-Based Liquid Crystals at the 207th ACS national meeting, San Diego, March 1994. $2,000

Tze-Chiang Chung, on behalf of the ACS Division of Polymer Chemistry Inc. Transition Metal Chemistry and Polymerization at the 207th ACS national meeting, San Diego, March 1994. $2,000

Boualem Hammouda, on behalf of the ACS Division of Polymeric Materials: Science & Engineering Inc. Scattering from Polymers at the 208th ACS national meeting, Washington, D.C., August 1994. $2,000

Paul M. Hergenrother, James A. Moore, on behalf of the ACS Division of Polymer Chemistry Inc. Thermally Stable Polymers at the 207th ACS national meeting, San Diego, March 1994. $2,000

David C. Johnson, on behalf of the ACS Division of Inorganic Chemistry. Synthesis, Structure, and Properties of Meta-Stable Compounds at the 208th ACS national meeting, Washington, D.C., August 1994. $2,000

Daniel M. Neumark, William H. Miller, on behalf of the ACS Division of Physical Chemistry Inc. Chemical Dynamics in the Gas Phase at the 207th ACS national meeting, San Diego, March 1994. $2,000

R. Paul Philp, on behalf of the ACS Division of Geochemistry Inc. Reservoir Geochemistry at the 207th ACS national meeting, San Diego, March 1994. $2,000

C. Keith Riew, on behalf of the ACS Division of Polymeric Materials: Science & Engineering Inc. Toughened Plastics: Science & Engineering at the 207th ACS national meeting, San Diego, March 1994. $2,000

James P. Runt, on behalf of the ACS Division of Polymeric Materials: Science & Engineering Inc. Dielectric Spectroscopy of Polymers at the 207th ACS national meeting, San Diego, March 1994. $2,000

Jean'ne M. Shreeve, on behalf of the ACS Division of Fluorine Chemistry. George H. Cady Symposium on Fluorine Chemistry at the 207th ACS national meeting, San Diego, March 1994. $2,000

Donald W. Slocum, on behalf of Catalysis & Surface Science Secretariat, Divisions of Petroleum Chemistry Inc. and of Industrial & Engineering Chemistry Inc. Methane and Alkane Conversion Chemistry at the 207th ACS national meeting, San Diego, March 1994. $2,000

Martin R. Tant, on behalf of the ACS Division of Polymeric Materials: Science & Engineering Inc. High-Temperature Properties and Applications of Polymers and Polymer Composites at the 207th ACS national meeting, San Diego, March 1994. $2,000

Patrick H. Vaccaro, on behalf of the ACS Division of Physical Chemistry. Modern Optical Tools for Probing Molecular Processes at the 207th ACS national meeting, San Diego, March 1994. $2,000

Mark L. Wells, on behalf of the ACS Division of Geochemistry Inc. Colloidal State in Seawater at the 207th ACS national meeting, San Diego, March 1994. $1,000

ACS-PRF Summer Research Supplements to Type AC Grants

Norman L. Allinger, U of Georgia. Ab Initio Calculation of Heats of Formation. $5,000

Richard Bersohn, Columbia U. Tests of Mode-Selective Chemistry in Polyatomic Molecules. $5,000

William H. Breckenridge, U of Utah. Spectroscopic Studies of the Electronic Interactions of Ground- and Excited-State Atoms with Small Molecules. $5,000

Carlton E. Brett, U of Rochester. Dynamic Stratigraphy, Physical Sedimentology, and Paleoecology of Mid-Paleozoic Black Shales of the Northern Appalachian Basin. $5,000

Kenneth G. Caulton, Indiana U. Pi-Donor-Stabilized Unsaturation: Principles and Applications. $5,000

Valerian T. D'Souza, U of Missouri, St. Louis. Novel Cyclodextrins: Synthesis and Properties. $5,000

Steven G. Driese, Claudia I. Mora, U of Tennessee. Stable Isotope Composition of Pedogenic Carbonate in Central and Southern Appalachian Red-Bed Sequences: Monitor of Elevated P_{CO_2} during the Paleozoic? $5,000

Richard S. Givens, U of Kansas. Mechanistic and Exploratory Investigations of Hydroperoxyester-Induced Chemiluminescence. $5,000

Robert R. Holmes, U of Massachusetts. Hypervalent Cyclic Oxyphosphoranes as Catalytic Reaction Intermediates. $5,000

Bernard Kirtman, U of California, Santa Barbara. Accurate Calculation of Electron Correlation, Nonresonant Frequency Dispersion, and Vibrational Distortion Effects on Nonlinear Optical Properties of Conjugated Polymers. $5,000

Kenneth B. Lipkowitz, Indiana U-Purdue U, Indianapolis. Enantiodiscrimination on Chiral Polymers. $5,000

James M. Lisy, U of Illinois, Urbana-Champaign. Effect of Hydrogen Bonding on Vibrational Transition Moments. $5,000

Austin Long, U of Arizona. Stable Chlorine Isotopes as Indicators of Source and/or Evolution of Basin Brine. $5,000

J. Casey Moore, U of California, Santa Cruz. Faulting, Dolomitization, and Fluid Migration in the Monterey Formation in the Santa Maria Basin, California. $5,000

George R. Newkome, U of South Florida. Metallospheres and Superclusters: Preparation of Cascade Mediomolecules Possessing Interior Metal Centers. $5,000

John P. Oliver, Wayne State U. Synthesis, Nuclear Magnetic Resonance, and Structural Studies on Organoaluminum Compounds. $5,000

Arnold L. Rheingold, U of Delaware. Diphosphenes and Diarsenes in Cluster Synthesis: Preparation of Metal/Main-Group Multiple Bonds. $5,000

Paul W. Schmidt, U of Missouri, Columbia. Small-Angle X-ray Scattering Studies of Processes on Pore Surfaces. $5,000

Johannes Smid, State U of New York, C of Environmental Science & Forestry. Novel Amphiphilic Hydrogels with Immobilized Cation-Chelating Ligands. $5,000

ACS ombudsman

As a service to members of the American Chemical Society, an ACS staff office of ombudsman, which was established in 1976, provides a focal point for members to voice ideas and concerns, and primarily to solve nonroutine customer service problems. For such matters, please contact the ACS ombudsman by phone at (800) ACS-5558, select 5, then 4; or write to 1155—16th St., N.W., Washington, D.C. 20036. Members are also reminded that society councilors and directors are available to hear and act upon complaints and requests.

ACS-PRF Summer Research Supplements to Type B Grants

Timothy W. Hanks, Furman U. Polymerization of Transition-Metal Complexes Containing Heterocyclic Ligands. $5,000

Rabindra N. Roy, Drury C. Thermodynamic Study of Electrolyte Mixtures. $5,000

ACS-PRF Summer Research Supplements to Type C Grants

Harry L. Frisch, State U of New York, Albany. Chemical Physics. $5,000

ACS-PRF Summer Research Supplements to Type G Grants

Mary K. Boyd, Loyola U of Chicago. Photochemistry of 9-Xanthylium Ions. $5,000

Erik J. Fernandez, U of Virginia. Magnetic Resonance Imaging Analysis of Miscible Viscous Fingering in Porous Media. $5,000

Philip D. Hampton, U of New Mexico. Magnetic and Conductive Properties of Metallo-Tripos Polymers. $5,000

Steven P. Nolan, U of New Orleans. Thermochemistry of Olefin Iron Carbonyl Complexes: Thermochemistry Related to Olefin Catalysis. $5,000

Piotr Piotrowiak, U of New Orleans. Intramolecular Excitation Transfer Bands. $5,000

Bradley D. Smith, U of Notre Dame. Synthesis and Study of Photoresponsive Receptors and Catalysts. $5,000

Jing Li, Rutgers, State U of New Jersey. A New Class of Solid-State Materials: Synthesis, Structure, and Electronic Properties of Novel Quaternary Transition-Metal Telluride Compounds. $5,000

Call for papers for fluorine conference

The ACS Division of Fluorine Chemistry will hold the 12th Winter Fluorine Conference at the Tradewinds Hotel in St. Petersburg Beach, Fla., Jan. 22–27, 1995. Papers are being solicited in all areas of fluorine chemistry for both oral and poster presentations. Any paper that is submitted for consideration must be accompanied by both a 150-word abstract and a 1,000-word abstract. Poster papers need only be accompanied by a 150-word abstract. Abstracts should be submitted on the standard ACS Abstract Form no later than Sept. 16. To submit an abstract or for additional information, contact general chairman Joseph S. Thrasher, University of Alabama, Department of Chemistry, P.O. Box 870336, Tuscaloosa, Ala. 35487; phone (205) 348-8434, fax (205) 348-8448 or (205) 348-9104. ☐

Nitric acid concentration specification change

The ACS Committee on Analytical Reagents revised the ACS specification range for nitric acid concentration from 69.0–71.0% to 68.0–70.0%. The action was taken to facilitate compliance with the new HM-181 packing group system that has been adopted by the Department of Transportation to be effective as of Oct. 1.

Currently, nitric acid with a concentration range of 69.0–71.0% is shipped in packages that meet packing group II requirements. The new regulations will require that nitric acid concentrations greater than 70% be shipped in packaging that meets the more stringent packing group I requirements.

Major volumes of nitric acid with a concentration of 70–71% are routinely shipped in 2.5-L bottles and 6.5-gal carboys. If the specifications had not been revised, significant changes in packaging would have had to have been made by Oct. 1. A similar specification change was approved by the Semiconductor Equipment & Materials International Organization during its July 19 Process Chemicals Committee meeting.

The change in specification means that the normal azeotrope of 68.4% nitric acid now falls within the ACS specification range. ☐

ACS journal chooses advisory board

The advisory board of the *Journal of Physical & Chemical Reference Data* has been appointed. New members are John Herron, Ronald N. Lee, and Joseph J. Villafranca. Continuing to serve are David W. Bonnell, Peder J. Estrup, Leonard V. Interrante, John C. Light, Sokrates Pantelides, and Wing Tsang. The terms of Thomas F. Koetzle and Edward W. Thomas have expired. A list of advisory board members for other ACS publications is in C&EN, May 16, page 53.

CHEMICAL & ENGINEERING NEWS

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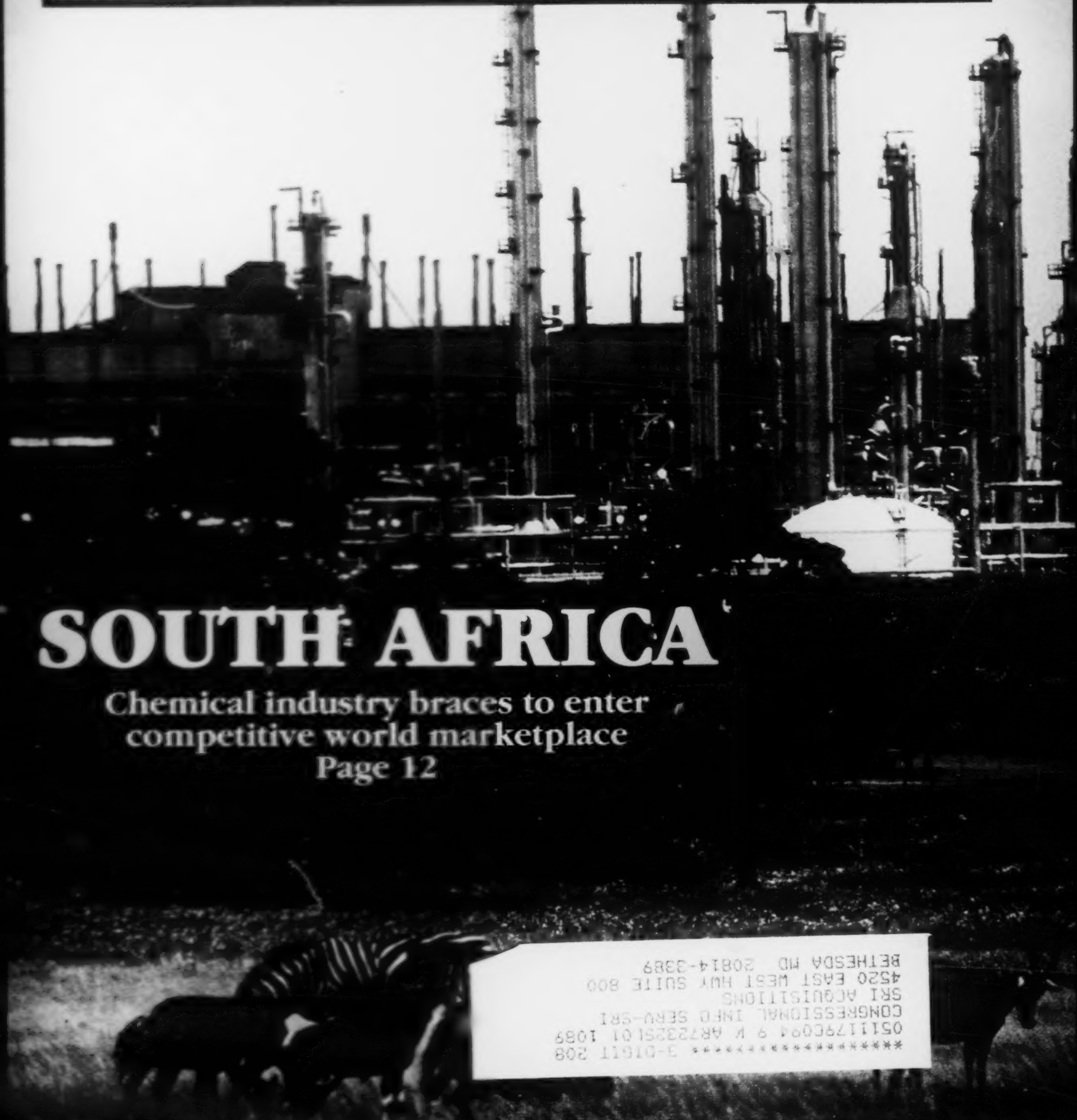

SOUTH AFRICA

Chemical industry braces to enter competitive world marketplace

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C&EN
AUGUST 8, 1994

NEWS OF THE WEEK

- Clinton Administration unveils eagerly awaited report on national science policy. Page 6
- White House also announces members of Presidential science advisory panel. Page 6
- Holographic data storage and retrieval system based on use of a photorefractive crystal shows promise for computer applications and image processing. Page 7
- In a move that would further consolidate the U.S. drug industry, American Home Products has launched a hostile takeover bid for American Cyanamid. Page 8
- Union Carbide and Italy's EniChem announce a joint venture to produce and market polyethylene in Europe, despite existing overcapacity for the polymer. Page 8
- Joseph Priestley's house in Northumberland, Pa., is dedicated as a National Historic Chemical Landmark. Page 9
- An FDA advisory panel finds that nicotine in tobacco products is addictive, but is unable to discern minimum level that leads to addiction. Page 9

COVER: Antelopes and zebras graze outside Sasol's coal-to-chemicals plant at Secunda, South Africa

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U.S. chemical trade surplus continues to decline as imports climb at a faster rate than exports. Page 26

Biotechnology companies showed mixed performance in the first half of 1994 despite increases in revenues. Page 27

GOVERNMENT

EPA sets plans to realign and strengthen its R&D operations following performance reviews; vows to become the premier environmental science organization in the U.S. Page 31

SCIENCE/TECHNOLOGY

Immobilized artificial membranes are now being used to predict drug transport across biological membranes and in the chromatographic separation and purification of proteins. Page 34

New enzyme-catalyzed stereospecific syntheses provide shorter routes to sulfur- and nitrogen-containing monosaccharides. Page 35

ACS NEWS

Career assistance for chemists—including workshops, the employment clearinghouse, publications, and advice from other chemists—is available through ACS Career Services. Page 40

COVER STORY

South Africa's chemical industry, long insulated by trade barriers and apartheid, prepares to compete globally—but must first address domestic issues such as an unskilled work force and high production costs. Page 12

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LETTERS

Find grads jobs—or else

When the effects of industrial pollution on the well-being of our planet were recognized, steps were taken to correct the problems. Chemical firms complied with governmental regulations to protect the environment. In fact, for many chemical firms today, environmental expenditures exceed research budgets.

Why is there not the same concern shown for the preservation of our technical manpower? Unless we take steps to find positions for technical graduates, we will arrest the influx of qualified students into the chemistry major programs of our colleges and universities.

Chemical firms need a continuous supply of creative personnel if they are to develop new products and remain competitive with firms in countries that promote the development of creative problem-solvers. This affects not only the well-being of the company but of our country as well.

The chemical industry should take the initiative before the government establishes a Technical Manpower Protection Agency (analogous to the Environmental Protection Agency) with the concomitant expansion of the bureaucracy.

George J. Beichl
Philadelphia

Entrepreneurs for independence

The economic status of chemists has received much attention in the past few years, as we might expect in a decline. Many suggestions—including certification or licensing, immigration control, and continuing education—were made by Attila Pavlath (C&EN, Dec. 20, 1993, page 45). In another letter (C&EN, Jan. 17, page 2), W. J. Vullo made a case for broadening the basic education for chemists.

I'm very much in favor of broadening the education of chemists, but I would like to do it with a target in mind that will make chemists more independent. I would like to see chemistry departments offer training in entrepreneurship—course work that details just how to get a new venture going. In so doing, the student must consider all aspects of the chemical business, from raising money to environmental concerns to marketing. Such training would be equally valuable in starting a new venture or working for a large corporation. The object is to make the chemist more independent.

As an early example of this approach, Carthage College, Kenosha, Wis., has established a Distinguished Professorship for Entrepreneurial Studies in Sciences.

Paul R. Story
Johnsonville, S.C.

No turning back

I am sitting at a campsite in Grand Teton National Park having read the two letters by Edwin A. Matzner and Frank A. Anderson headed "Science's costs, benefits" (C&EN, June 13, page 4) and remembering Bryan J. Cook's pessimistic letter (May 16, page 5) to which they were responding, indicating that science is the cause of many of our current problems. (The feature article on plutonium disposal problems [C&EN, June 13, page 12] didn't exactly refute Cook.) However, viewing these magnificent mountains, I tend to be optimistic, and I wonder if the discussion doesn't need to be broadened a bit.

Anderson's "four fundamental laws" are excellent and should be universally taught. I hope he won't mind if on occasion they are given additional (attributed) exposure. Unfortunately, his last paragraph essentially calls for abrogation.

Matzner's litany of inescapable scientific achievements is compelling, but does not address the question of their accompanying consequences—to date and forever more. It does, however, provide some evidence that there is a "fifth law": No action is truly reversible. (Note that doing nothing is an action.)

I propose that the problem is not science; it is philosophy (thought, knowledge, perception, whatever). We are creatures of actions with reasons (good, bad, scientific, emotional) rather than reaction by instinct. *"Homo whichever"* started us on this course when making the first tool,

Correction

- Aug. 1, page 6: Operating income from Dow Chemical's hydrocarbon and energy business finished this year's second quarter at $27 million, not $32 million as implied.

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South Africa's Chemical Industry Prepares To Enter Global Market

■ ***Emerging from cocoons of subsidization, firms must address high costs, lack of trained workers, environmental issues***

Patricia L. Layman, C&EN London

The rainbow coalition proclaimed by Nelson Mandela upon his inauguration as President of "new" South Africa marked the official end of the country's status as pariah.

The country is emerging to take its place on the world stage, dismantling trade barriers that have protected its self-sufficiency and insulated it from the heady competitive pressures of world markets. Its businesses and industries, in turn, are emerging from behind protective tariffs and restrictive laws—as well as sanctions imposed by other nations to protest apartheid—only to realize that high costs and inefficient infrastructures must change to ensure survival.

And the chemical industry, as one of the major industries in South Africa, is one of the leaders of that process of change. It has little choice. It is fighting to make a place for South Africa in one of the most international industries—an industry with no time for sentimental largesse for a rainbow country, even one whose transformation to multiracial democracy seems little less than miraculous.

South Africa is a market of about 40 million people, of whom about one sixth are white and the others are black, Asian, and what the country calls "colored"—mixed race. That is undoubtedly an attractive-sized market, but it is small compared with, for example, the more populous countries of southern Asia. India, by one estimate, has a middle class already nearly as large as that of the U.S., and it is expected to double to about 300 million by 2000, fueling demand for consumer goods and services—and chemicals.

Throughout southern Africa, however, growth potential for industry in the near future is quite limited. South Africa should be able to retain its dominance of the region's economy. South Africa's total gross domestic product (GDP) in 1993 was estimated at slightly less than $90 billion. That's more than three times the economies of all other southern African nations—Angola, Zimbabwe, Botswana, Zambia, Tanzania, Namibia, Malawi, Mozambique, Swaziland, and Lesotho—combined.

Within South African industry, the chemical industry continues to be a major contributor. In a study, "An Overview of the South African Chemical Industry 1993/1994," published by Council of Scientific & Industrial Research Information Services (Pretoria), author Colin Cook pegged total manufacturing sales in the country at $55 billion in 1992; of that, about 18% came from the chemical and process industries.

That percentage was slightly lower, he says, than in an earlier report he wrote, when statistics up to 1986 showed that chemicals and allied industries were about one fifth of all manufacturing in terms of value. One of the main reasons for the slip in percentage, he says, is the poor harvests over the past few years, reducing consumption of agrochemicals. In addition, lower levels of mining activity also have affected chemical consumption and production volumes.

Cook says 1992 chemical sales were about $9.32 billion, but that includes total sales of Sasol, the largest company in the sector. Stripping out Sasol's sales of liquid fuels and coal brings the total down to about $7.25 billion in 1992 and just shy of $7.30 billion in 1993.

That figure puts the country's chemical industry on a par with that of Sweden, for example, which had sales of $7.20 billion in 1993. Sweden, however, has a population of only about 9 million people. On the other hand, Poland has a population of 38 million, roughly equivalent to that of South Africa; Poland's chemical industry in 1993 totaled about $5 billion, according to statistics compiled by CEFIC, the European Chemical Industry Council, located in Brussels.

A recent company newsletter at Dutch chemical producer Akzo Nobel notes that "the South African market is unique in its diversity. Marketing efforts have to be directed to English, Afrikaaner, Asian, and 16 African tribes, all with different languages and cultures. Distances between towns are enormous—for example, the distance between Cape Town and Johannesburg is [about 1,000 miles]. However, the road, rail, and air networks are excellent."

In fact, the country's spaciousness has probably helped contribute to its chemical industry's earlier comfort within its own borders. Ian van Schalkwyk, manager for the industrial chemicals unit of Hoechst South Africa, a subsidiary of Germany's Hoechst, put it this way: "The history of the industry here has been of restrictive trade practices: government subsidization and isolation from competition. Most of the technology is dated, and plants are small, inward-looking, for serving local demand."

One result has been that the industry has suffered "a significant decrease in real sales growth" in recent years, says van Schalkwyk. Between 1973 and 1980, average annual real growth of chemical sales was 8.8%, which fell to 4.5% per year in the period 1980–85, and declined at an average annual rate of 1.8% between 1985 and 1990.

"We've had decades of import replacement and were more protected than was desirable," agrees John Job, managing director of Sentrachem, South Africa's second largest chemical company. That policy, in turn, shaped the industry, promoting the development of four major companies—AECI, Sentrachem, Hoechst South Africa, and Sasol.

Zebras and antelopes graze near Sasol plant at Secunda, South Africa.

Those four firms accounted for more than 40% of the chemical sales in 1993; by contrast, more than 300 small- and medium-sized companies accounted for only 35%. The rest of the sales came from the 15 to 20 multinational companies operating in South Africa.

Tariff protection

One of the major ways in which South African industry has been sheltered has been in tariff protection, as well as tightly controlled limits on some items. The government thought such import restrictions "would lead to development, but they didn't," observes H. W. E. Schmidt, manager of market intelligence and special projects at Hoechst South Africa.

Instead it led to plants sufficient for local demand but not for international competition, with high unit costs and sales prices. That was acceptable under the circumstances. If imports coming in were threatening local industries, the tariffs were raised. It was a cozy situation, one which benefited the supplier but certainly not the customer. According to one purchasing agent, the general attitude of chemical companies was, "Either you buy the product or not, we don't care." And producers did not need to look at exports, because domestic markets took all their production.

With the signing by the South African government of international trade policies set by the General Agreement on Tariffs & Trade (GATT), there will be substantial changes, Schmidt says. "The real world will be happening for the South African chemical industry."

South African tariffs on all products will be reduced over a period of years from an average of 21% to an average of 15% across the board, and tariff headings will be reduced from the more than 100 currently to six. According to Schmidt, more products will be grouped under one heading, with tariffs reduced or eliminated. However, some products may be put in a tariff group for the first time and thus have tariffs applied. Ironically, many of the chemicals imported by the industry will be among those with new tariffs.

According to the World Bank, South African tariffs have been about average for a developing country, although they are considered to be very high by industrialized nation standards. Additionally, the dispersion, complexity, and instability of the system have undermined economic efficiency. The net effect has been a heavy bias against exports, two thirds of which stem from the higher input prices that industry must pay for raw materials. The South African Chamber of Business has estimated that manufacturing costs are 15% above the average for countries of the Organization for Economic Cooperation & Development (OECD), because companies pay 25% more for their raw materials than their competitors in industrialized countries, and because capital costs and labor costs, adjusted for productivity, are higher.

The industry's success will all come down to the question of competitiveness, argues Vincent Lovell, executive director of Sentrachem, and to a great extent that depends upon the relationship between government, labor, and capital.

"We must ensure that these [entities] work together, not as antagonists," he says. "Government must not be too interfering, industry not collusive, and labor not [demanding of] too-high wages. We must have the right balance."

Competitiveness components

Lovell sees a number of components to competitiveness—including raw materials, technology, logistics, market accessibility, and fixed costs. As for raw materials, South Africa has minerals and coal, agricultural products, and off-shore petroleum. The country still has single-channel marketing boards from the old "seige economy" days; this must change, Lovell says, and the industry must create high-value markets by product differentiation.

The country's technology, he says, is mainly imported. This has limited importance in commodities but is vital in spe-

Restructuring changes the landscape at AECI

AECI, the largest chemical company in South Africa, posted sales in 1993 of $1.61 billion, up 8% over 1992. Operating profits also increased 8% to $126 million, and net profits, before a nonrecurring gain, were up 26% for the year to $56 million.

The first half of this year, however, has shown the initial effects of major joint ventures established and reorganization measures completed in 1993. Sales for the first half were $672 million, down 11% from last year's first half, as the company's accounts reflected loss of sales of polymers now in Polifin, a joint venture with Sasol, and of explosives, assigned to a joint venture with ICI.

But net profits, before nonrecurring gains, of $22 million for the half showed substantial improvement, up 34% from the year-earlier figure.

For chairman Michael Sander, the need of South African industry to meet a growing international challenge has become one of the major forces shaping the chemical industry—and AECI. As he notes, "For South Africa to succeed, we [the country] have to achieve a growth rate of more than 5% per year. We can't do that just on our domestic market. Most of us [in manufacturing] now are looking at external markets."

In fact, for AECI, he adds, the test for investment in business areas is simple: "Can we make money in exports with this product? If not, we won't invest in it. It's a tough criterion, but the only sane one."

The philosophy, Sander adds, has paid off as the political changes have occurred in South Africa over the past several years. "Our response to the change has not been instant, but we began changing our mind-set. We began funding R&D that is beginning to pay off now."

AECI at a glance

Headquarters: **Johannesburg**

Sales: **$1.61 billion in 1993**

Operating profit: **$126 million in 1993**

Net profit: **$56 million (before nonrecurring gain) in 1993**

Major product areas: **Organic chemicals; paints and coatings; fertilizers and animal feeds; resins and nylon fibers, including tire cord; plastic products, including acrylic and urethane automotive parts and construction products**

Joint-venture areas: **Hydrogen peroxide, detergent-grade sodium tripolyphosphate, formaldehyde and urea-formaldehyde resins, aluminum sulfate, soda ash, titanium dioxide, explosives, chlor-alkali, polyvinyl chloride, and polyethylene**

The compelling need to compete on an international level did spur the company's two major restructuring moves last year: formation of an olefins and polymers joint venture with fellow South African industrial giant Sasol, and swapping AECI's explosives business to ICI in return for 25% of ICI's 39% shareholding.

"We had been very close to another joint venture with Sasol earlier, but couldn't quite do it," recalls Sander. "The logic wasn't as strong. This time, the conviction grew in our minds: To be competitive in petrochemicals, you must have competitive feedstocks, with cash costs as low as the most aggressive in the world. Sasol is there," with its olefins-from-coal supplies.

The company is also considering new acetylene technology. "Our aim is to make acetylene as cheaply as ethylene. It's a very valuable raw material; it's just too expensive right now. It's one of those projects that should be looked at carefully before it is discarded out of hand."

At the top of the list of potential new areas for AECI is the biochemical industry. "It is in its early days now, so there is a better chance to become active in [the industry] without being wiped out by the international giants." Sander continues, "We think we have jolly attractive feedstocks—sugar and maize—for biological fermentation. We already are in nutrition, with commodity products such as vitamins and phosphates." The company is well under way, for example, with construction of a plant to make lysine from sugar industry byproducts, using its own fermentation technology. The plant is expected to be on stream in mid-1995.

In commodity areas, the company is dogged by the current state of the soda ash market, which is the source of the red ink plaguing Soda Ash Botswana, a joint venture in neighboring Botswana in which AECI owns 25%. "There is nothing wrong with the project; the timing is wrong," Sander insists. "When we built the plant, the market was 750 million lb per year. Now it is 507 million lb, and world prices are low.

"In due course, the market will return, and the prices will go back to normal. For now, we grit our teeth. But it was an important project. It was conceived and done when things were not terribly encouraging in South Africa. And it was done on a regional basis: It wasn't just South Africa versus the rest of Africa."

cialties. "We must concentrate on niche specialty chemicals." Its markets, he says, consist of small domestic and regional trade blocs and are characterized by geographic isolation. "We must globalize."

And as for fixed costs, he points out tremendous changes during the past two years. The tax rate has come down from 47% to 43%; inflation has also declined. As time goes on, these rates should improve, Lovell says. However, low productivity is the big problem: South African workers' educational and skills levels are significantly lower than those of competitors. "Education and training are the answer, but that is easier said than done."

The whole situation, he adds, is "particularly challenging in a relatively small economy. If you want to compete, you must compete on a world scale, for world markets. We have to go down the value-added chain, be more in specialty chemicals, and work those niches better than we have been."

Many of the same ideas are expressed by Michael Sander, chairman of AECI, the largest chemical producer in South Africa. "For the manufacturing industry in general," he asks, "what's the best thing for our country? To expand substantially our manufacturing sector, by adding value. What is the best way to do that? It must be to bring technologies and good practices to this country, and to encourage and make space for the products made here.

"GATT changes, on the whole, will be good," he adds. "We will have to become more competitive. There will be a need for a lot of help to get production up to world standards. Where I would like to see [President Bill] Clinton put his money is in education, helping us that way. We have a tremendous amount of catching up to do."

As for the chemical industry, says Sander, "the opportunity to trade internationally has been with us for sometime. Sanctions fell away a while ago. We are regaining positions in export markets. Business has been quite depressed, but, during a difficult time, we have regained quite a lot. I'm pretty optimistic that we will have a good second half, and 1995 has the hallmarks of being a good year. Business is okay—for the first time in quite a few years, really. We've had a hard time, and as the barriers come down, we'll recover rapidly.

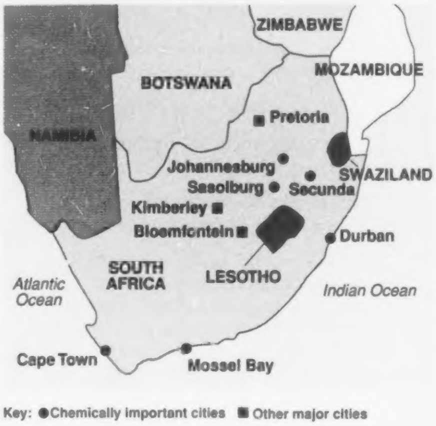
"We had to learn to be competitive," Sander adds. One way in which AECI addressed the subject was to form a joint venture in monomers and polymers with Sasol. The resulting venture, Polifin, is considered a world-scale competitor, more than able to hold its own among petrochemical giants around the world.

That was a sensible course of action, says Ronnie Hampel, chief executive officer of Britain's ICI, which until last year held 39% of AECI. "My general view is that South Africa has a strong domestic economy, some high-quality businesses, and a strong raw materials position. It has to adjust to the world competitive scene, subject to world competitive pressures," Hampel says.

"As we have been exiting from commodities and petrochemicals elsewhere in the world, it seemed sensible to exit petrochemicals in South Africa, from AECI." Hence the company cut back its shareholding to 13% in exchange for a 51% stake in AECI's explosives business. But in the course of that deal, Hampel notes, "we were instrumental in the deal between AECI and Sasol—it has to be world competitive."

Sander points out that "this has been an inward-facing industry. Exports were opportunistic. It was a rare company that invested for export opportunities, before. Now with the flick of a switch, and GATT nearly final, sanctions have dropped and financial and markets access are open. We have lots more competition from outside. You have to respond; you have to export. If your market share in your own market goes down, you have to look at other people's markets."

Important chemical-producing sites are located in several cities



Indeed, "exports" seems to have taken on the air of a rather determined mantra in the industry. Sentrachem's Job, for instance, emphasizes exports along with increasing internationalization for the company. "I'm confident about what South Africa can achieve and what the chemical industry can achieve," he says. "I hope in our move into those overcrowded world markets we will find collaborative opportunities and not have to cut and thrust every step of the way, but we will if we have to. Defense is never a sufficient strategy; defending strong small markets that are no longer protected is not an adequate strategy. We're at a crossroads now, not only for the country, but also for the industry."

However, he also points out that internationalization is a two-edged sword. One edge benefits the company, the other penalizes it as former opportunities are closed by wary competitors.

That is particularly true, he says, with R&D. "The old way of going and buying technology almost always has a tight geographic constraint on where you can sell the product," he says. "If you're going to export and sell more internationally, it will be more difficult to get licenses. We've already run into a couple of examples of that.

"In those areas, you have to be more self-sufficient in technology. People just won't sell licenses other than in standard lines where it is almost commodity technology. If you want anything more differentiated, you have to do it more yourself." Companies will protect their interests by holding more closely to intellectual property, now that GATT is limiting the financial means of protecting themselves, Job suggests.

Four companies dominate the chemical industry

Millions	Sales, 1993
AECI	$1,613
Sentrachem	709
Hoechst South Africa	378[a]
Sasol Chemical	335[a]
SUBTOTAL	$3,035
Other top 15 to 20 multinational firms	1,684
Medium-sized 10 to 15 domestic producers	950
Roughly 300 small- to medium-sized domestic producers	1,630
TOTAL	$7,299

a Estimated. **Sources:** CSIR Information Services. C&EN estimates

Developing a country

The chemical industry may be gearing up to increase exports and international operations, but it will also be keeping a close eye on the implementation of President Mandela's reconstruction and development program, by which he has pledged to reshape South Africa.

The country has tremendous variations in development throughout its nine provinces, established earlier this year from the former five. Western Cape Province, around Cape Town, is the most highly developed, with the highest disposable income per capita and the most education beyond primary school. However, according to a study by the Development Bank of Southern Africa, the average income per capita for blacks is highest in the Pretoria-Witwatersrand-Vereeniging Province, around Johannesburg, at $2,534 per year, compared with the $417 in the Northern Transvaal Province, in the northeast region of the country.

One can also see such contrasts in the black townships themselves. For exam-

Individual units thrive at 'central' Sentrachem

Sentrachem, the second largest chemical company in South Africa, had sales in 1993 of $709 million, up 8% over 1992. Net profits, at $24 million, showed even more improvement, up 21% over 1992, despite increased exposure of the South African economy to international competition and depressed growth in the domestic market owing partly to continued violence.

With the 1994 elections and the new government, however, the economic picture is stabilizing, says managing director John Job. Now, in fact, he says, "actual business conditions are not bad. They are not brilliant, but not bad. I'm feeling fairly relaxed and looking forward to better things."

As the industry has come through the past few "stringent" years, he adds, Sentrachem and other companies have come "to grips with their inefficiencies." The basic result: Sentrachem is closing down some businesses that were successful in the old order and starting new ones that will be relevant for the new economic order in South Africa.

Such closing and starting is perhaps easier for Sentrachem than it would be for many other companies because of the nature of its structure—a collection of various chemical units pulled together into one company. That, in fact, is the source of the name Sentrachem—derived from the Afrikaans term that means pulling to the center. The company was formed in 1967 as an agglomeration of several smaller firms.

"That is paradoxical," says Job, "because we've continued to respect the approach of having individual companies. We are almost a business federation, but generally in chemicals."

That structure, he says, gives the company a built-in flexibility to meet customer needs. On the other hand, in the years shortly after the company was formed, "collective strength" proved a seductive, but dangerous, notion. Sentrachem was lured into launching a series of substantial investments, some of which went seriously wrong. By the time company management began to sort out the investments during the mid-1980s, the company was "really in a survival mode," Job says.

"That's where we were 10 years ago," he admits. From there, the firm "ran an intermediate phase. Having survived, we had to reconstitute ourselves." That led to an investment program of roughly $450 million from the late 1980s through the early 1990s to build up a major asset base.

The main focus for the company now is balancing a few selected commodities and an increasing selection of high-value-added products. At Sentrachem, "We're not going to exit commodities or deliberately scuttle them. But those activities will be more inactive in international markets. They won't give us the boost into the international marketplace," on which he is putting strong emphasis. Sentrachem saw a 29% rise in exports in 1993; exports constituted 13% of group sales. Job says the company's goal is to boost exports to 25% of sales over the next three to four years—or sooner.

In fact, he adds, Sentrachem will be focusing its investments on areas where it can "export effectively and profitably." That, he suggests, inevitably leads to "greater concentration of efforts in more sophisticated areas—adding value, conducting chemicals processes, and providing quality and service to match our products. As we go forward, we may well change our portfolio, but it's pretty neat now."

The "center" of Sentrachem "provides the guidance," Job says. "We are more than a holding company; we are chemical industry boffs"—experts. "We may add and subtract from these divisions, and as time goes by, we will. We don't, for example, rely solely on the divisions to find their own acquisitions or products to go into; we have our own ideas as well.

"Quite a bit of my time now," Job adds, "is spent in identifying and creating those opportunities" for mergers and acquisitions, particularly those taking Sentrachem into manufacturing in other parts of the world.

The company already has some 13 joint ventures, primary among them is Safripol, a 50-50 joint venture to make polymers with Hoechst that was formed 20 years ago, and a new one with Sasol, to make alkylamines.

The possibility of forming international ventures is important, says Job, because "what we believe is that Sentrachem is competent in joint ventures. We know what [the partners] require and how to manage them, as one side of the partnership. That is very acceptable as a way forward worldwide."

Sentrachem at a glance

Headquarters: Sandton, suburb of Johannesburg

Sales: $709 million in 1993

Operating profit: $57 million in 1993

Net profit: $24 million (before nonrecurring charges) in 1993

Divisions and major products: Agrihold/Sanachem—agrochemical production and distribution; Karbochem—synthetic rubber, processing and mining chemicals; NCP—organic chemicals (including ethanol), water purification compounds, enzymes, and chlorine, caustic soda, and specialty derivatives (including swimming pool sanitizers),; Mega Plastics—plastics products, including containers, tubing, automotive components, and insulation; Chemical Syndicate—unsaturated polyester resins

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ple, the largest township, Soweto—South West Township—is a collection of some 30 communities ranging from what is called "Beverly Hills," complete with Maseratis behind iron gates to small neat houses, many with lovingly tended flower gardens by the door, to squalid squatter camps.

Soweto, like most of the townships, started when gold mines were still worked around Johannesburg. The mining companies needed labor for the factories serving the mines. Black workers originally lived in the west part of Johannesburg, sharing land with whites. Then land acts shifted them to separate areas in the south, and these communities have grown ever since.

Official statistics include Soweto as part of the population of greater Johannesburg: 596,000 out of a total of 1.9 million. Sowetans, on the other hand, say their population is more than 3.5 million—an illustration of the difficulty in pinning down a community in flux. The township's 30-odd communities occupy 47 sq miles, have 369 schools, one university (opened in 1982), one teachers' training college, and one hospital—the largest in South Africa—which treats 1.3 million patients each year.

The township also has an unemployment rate of at least 40%. Most of the population growth comes from an influx of people from outside the area, because more and more long-time residents are limiting their families. Says one bus driver in Soweto: "I'm having only two children, so they can get a better education. I don't want them to be tour guides—the Minister of Tourism, perhaps!"

Health, housing, and education are among the top priorities for the reconstruction and development program—areas in which the chemical industry can make significant contributions with pharmaceuticals and materials, for example, points out Hoechst's managing director Reinhard Traub.

The African National Congress' (ANC) political platform called for raising the health budget from 3.4% of GDP to 4%—roughly $3.6 billion to be spent over five years—to create a single integrated national health care system based on primary health care and funded mainly through existing taxation.

This was partly addressed by the budget prepared by Mandela and his Cabinet earlier in June—"sin taxes" included excise on cigarettes raised by 25%, and on some beer types by as much as 33%. These tax-derived monies augment funds shifted from other government departments, such as defense.

In other areas, the country's minister for water affairs and forestry, Kader Asmal, aims to create a national water and sanitation program that would help all households to secure a clean and safe daily water supply of 5 to 7 gal per person within a distance of 200 yards of their homes. The new policy has been developed to combat the situation that was created under apartheid, when more than 12 million people did not have access to clean drinking water, and 21 million did not have proper sanitation and refuse removal.

And on yet another front—housing—national housing minister Joe Slovo has committed the government to building 1 million housing units within the next five years.

C&EN staff photos

Government goal is to provide houses like those in Soweto (right) for people now living in squatters' towns (above).

For every $270,000 invested in housing, Slovo says, 120 jobs are created. That is five times better, he notes, than the employment benefit of investing in textiles, for example. Housing also creates a consumer market for electrical goods and leads to development of roads and water systems.

Slovo's program takes in a research project by consulting agency CSIR to test different building methods for housing. The buildings that have been tested are made from materials ranging from pressed grass cuttings to steel. One prototype from the refrigeration industry used a polystyrene core inside of steel walls; another used cardboard impregnated with resin—which people didn't like because of the hollow sound it gave off. The pressed straw began to sprout grass, although it was suitable in other ways.

Whatever materials are selected, there will probably be no one style. Local materials will be important. Communities near lumber mills will build timber-frame houses, and those near steel plants, houses with pressed-steel walls and roofs. Hollow concrete blocks will probably also be widely used. And although roofs could be anything from glass-reinforced plastic to thatch, metal sheeting and cement tiles appeared to be the most popular choices among the CSIR prototypes.

Unskilled labor force

The lack of skilled workers will be one potential control on economic growth, government analysts and private-sector economists agree. According to AECI's Sander, experienced, qualified blacks are in great demand now in South Africa.

That assessment is backed up by recent studies by South African consultants who indicate that companies are prepared to pay black senior managers up to 50% more than their white counterparts.

Says Sander, "We've put a lot of time and money into developing our people, only to lose many of them to other companies. But then, as a leading company, you have a responsibility to develop people for the whole country."

He supports the idea of an industry training board; responsibilities for training employees should be unilateral, he says. "The number of people in the country qualifying with sufficiently good grades in math and science is woefully small—of whatever race. When the economy picks up, we will be massively short of people. We will have unemployment and shortages of the people who are needed—a contradiction."

One result of a shortage of educational and occupational skills is an emphasis among chemical companies on training their people—and, in some cases, their customers.

For example, for almost seven years,

Self-sufficiency reigns at Hoechst South Africa

As the third largest chemical company in South Africa, Hoechst South Africa is well on its way to topping $400 million in sales this year. The subsidiary of German chemical giant Hoechst passed $270 million in sales in 1991, but these figures expressed in South African rands provide more meaningful progress markers: 1 billion rands in 1991, 1.5 billion in 1994.

And what makes that performance particularly noteworthy, according to managing director Reinhard Traub, is that almost 90% of sales came from local production. "This proportion of locally produced sales is far higher than that of Hoechst locations in the U.S. and Europe," he points out. Hoechst U.K., for example, domestically produces only about 50% of its sales.

Moreover, although plastics in various forms and grades account for 43% of sales, he adds, "We are probably the most diversified chemical company in South Africa." The product slate varies widely, from biaxially oriented polypropylene film to veterinary pharmaceuticals to pigment preparations. Hoechst also conducts pharmaceutical and agrochemical R&D in the country.

As Traub sees it, a broad product range will be needed by chemical companies working to serve a country like South Africa, which in part is very underdeveloped.

"Given the discrepancies in population and wealth, meeting the basic needs of people will require a much greater emphasis on the provision of clothing, food, housing, health care, and education," Traub says. The company plays a strong direct role in the first four categories.

And in the area of education, the company's Social Responsibility program comes into play. This is a multifaceted program that extends from children's education to helping in the formation of and ongoing support for small businesses run by black entrepreneurs.

Among the facets of Hoechst's Social Responsibility program are the following:

- Support for black teachers to upgrade their qualifications.
- Extra lessons at schools for employees' children to help prepare for year-end exams and for the equivalent of high school graduation; and a primary school for children of employees at Hoechst's research farm in the northeast of the country, which is also open to other local children.
- Scholarships for employees' children to enable them to have post high school education.
- Business development services to assist promising black entrepreneurs in setting up their own small factories to produce detergents, cosmetics, car care products, and other household products.

The Business Development Services unit was set up by Hoechst seven years ago, in part to help train a pool of black entrepreneurs with interest in chemical businesses. There was a very limited supply of such people, primarily because—until 1979—blacks were not allowed to run their own chemical manufacturing businesses in South Africa.

Hoechst provides an assistance package to the startup businesses, including raw materials, marketing assistance, business skills training, and followup consultation. In some cases, Hoechst is a customer for the products that have been manufactured.

Bernard Magabe, who is responsible for Hoechst's small business initiative, oversees the program. He also supervises young university graduates taken on by the small enterprises as part of the program's arrangement. These graduates are usually chemists and technicians who can put their education to work by formulating paints, adhesives, and other consumer products, for example, while acquiring business skills.

They also acquire the Hoechst "culture"—safety and environmental awareness, for example—that will stay with them when they join Hoechst at the end of their business internship with the entrepreneurs. According to Magabe, some 30 people have gone through the program.

Hoechst South Africa at a glance

Headquarters: Midrand, suburb of Johannesburg

Sales: $378 million (estimate) in 1993

Major sites and products: Chamdor, near Johannesburg—pigment preparations, polyvinyl alcohol (PVA) dispersions, polyphosphoric acid, polypropylene film; Cape Town—polyester staple fiber; Durban—textile auxiliaries, PVA dispersions, veterinary products, polyester staple fiber; Pretoria—pharmaceuticals, fine and pharmaceutical chemicals, toiletries and cosmetics

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Hoechst has had a business development program to develop entrepreneurial skills among black owners of small companies in chemical specialties or in distribution and product handling. When Hoechst moved to new headquarters outside Johannesburg in May 1991, it sold its former head office site and buildings in the city to the government-sponsored Small Business Development Corp. (SBDC). Hoechst, as part of the deal, bought an equity share in SBDC. Under the arrangement, the buildings on the site were converted to provide premises, services, and training for small business entrepreneurs.

Sentrachem runs two projects in training and education. One, Sentravision Bridging School at its Sentrachem Gardens headquarters, opened last year. The school has 12 students who are improving their science and math grades and working toward high school graduation. In the other project, in collaboration with the science faculty at the University of the Witwatersrand, Johannesburg, Sentrachem sponsors a multimedia science education program for high school pupils.

Sentrachem's Lovell says: "Since the 1970s, we have had great success in teaching people single skills. Now, we need to teach multiple skills. Just to do one job is not sufficient—you have to do a number of jobs. The concept is one of the important things we've got to teach."

Role of labor unions

Whether that concept will be welcomed by South Africa's unions, however, is another question. As has been noted by a variety of observers, one of South Africa's problems is that it has a labor force dominated by a small group of unionized black workers who have relatively high wages and secure jobs and who have effectively priced South Africa out of competition with the emerging economies of Asia and Latin America.

Unions in South Africa have 3.5 million members, or about one fourth of the economically active population. COSATU—the Congress of South African Trade Unions that was founded in 1985—has 1.3 million members, more than half of whom earn less than $300 a month.

This year has already seen the most industrial action since 1991, and with workers demanding substantial wage increases in the current round of negotiations, more major strikes are possible.

Labor observers figure that the newly aggressive attitude reflects raised expectations resulting from the economy's return to growth after a four-year recession and the belief that the new government will be much more sympathetic to wage demands than its white-led predecessor.

Government subsidies

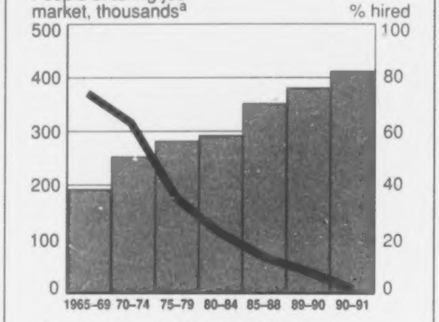
Just as labor unions are trying to work out their relationships with the ANC, now that it has become the party of power, the chemical industry is watching for signals concerning the government's relationship with the fuels and raw materials side of their business.

The government is currently wrestling with how to restructure its protection of the petroleum industry and whether it should offer any protection at all. Both Sasol and the relatively new Mossgas project, which has licensed Sasol's Synthol process for forming liquid fuels, are entitled to substantial protection. The government sets a support price for barrel equivalents, and if the market price of crude falls below that, the government pays the difference to Sasol and Mossgas. The support price just negotiated is $21.10 per bbl of oil; the current spot price for crude oil is about $17.50 per bbl.

What will happen to the entire support program is unclear. For example, President Mandela says he wants the industry to be on a break-even basis, but according to some sources, the new minister of energy is "making noises about wanting to expand" the program.

Until Mandela's ministers decide on any changes, however, Mossgas and Sasol will receive what a Sasol official sees as tariff protection for the synthetic fuels industry, but which all other industry observers and analysts consider a "subsidy."

Job creation is urgently needed in the new South Africa



[a] Average of yearly numbers for formal employment.
Source: Hoechst South Africa

Perhaps in the worry that the support required for the Mossgas project has pushed what cynically could be seen as a good thing over the edge of acceptability, there is little love lost between Sasol and Mossgas.

"We don't participate in the Mossgas project," a Sasol executive says firmly. "We had to sell our technology to Mossgas—the government demanded it. They have the technology now for processing [natural gas into liquid fuels]. We don't believe it's a viable operation. We're waiting to see what the new government does—Mossgass is very costly to run, and [it is] not cost-effective."

In fact, says one financial analyst in Johannesburg, "Mossgas will never earn a penny. The government was hoping the gas field would be better than it has turned out to be. The project would never have been undertaken on an economic base."

Sasol's Synthol process can be fed either with natural gas or with synthesis gas (a mixture of carbon monoxide and hydrogen) derived from coal gasification. At Sasol's coal gasification plants at Sasolburg and Secunda, low-grade coal is gasified in the presence of oxygen and steam to produce synthesis gas.

As the company describes the process, in the course of coal gasification using Lurgi technology and the purification of the resulting synthesis gas, various chemicals are produced—including cresols, some ammonia, and sulfur—all of which are marketed by the company or used in making fertilizers and explosives.

The purified synthesis gas goes through either of two versions of Fischer-Tropsch hydrocarbon synthesis, passing the gas over iron-based catalysts. The large fuel-synthesis plants at Secunda employ high-temperature technology and yield the equivalent of 120,000 bbl of crude per day. Sasol has now commercialized a fixed fluidized-bed Synthol reactor, which features lower capital costs as well as lower operating costs.

On the other hand, according to Sasol data, Mossgas was decided upon in 1987 and commissioned in 1992, when there was a decline in world oil consumption and growth rates. The price of oil had also dropped, from $28 per bbl to $12. The payback period, Sasol predicts, will be 36.9 years for the project, built to develop the natural gas

C&EN staff photo

Hoechst South Africa helps small enterprises like Shap Chemicals get set up and operating.

Coal and its gasification support chemicals growth at Sasol

Sasol, the South African Coal, Oil & Gas Corp., established in 1950, is synonymous with South African chemical industry. Its coal gasification and Fischer-Tropsch synthetic fuel production are almost legendary.

However, although Sasol, as an energy company, is one of the larger industrial companies in South Africa, it is only the fourth largest chemical company in South Africa. The firm breaks out chemical operating profits—for fiscal 1993 they were down 34% from the previous year—but does not indicate chemical sales, which are estimated at $335 million for fiscal 1993 compared with an estimated $319 million for the year earlier.

Results for the fiscal year ending June 30, 1994, will not be released until early September. However, results from the first half, which ended Dec. 25, 1993, showed that operating profits for the company as a whole were $300 million, up from $222 million in the comparable period a year earlier. Investments in petrochemicals helped lift operating profit margins, says Sasol managing director Paul Kruger. Net profits were $189 million, up 16%. Sales in the half year for the corporation were $1.26 billion, up from $1.17 billion in the previous year's first half.

"At the base of the whole gigantic pyramid of Sasol's synthetic operations," points out Kruger, is coal and its gasification. Three gasification plants have been built. The original one, built at Sasolburg in the early 1950s, has just been renovated—at a cost of nearly $220 million—to serve strictly as a chemical products plant. The other two, at Secunda, are synfuel plants, supplying both feedstocks to the chemical industry and refined fuels to the motor industry.

Part of Sasol's strategy development has been to determine an appropriate balance between the supply of chemicals and that of fuel. Sasol is using high-value petrochemicals to produce low-value liquid fuels. The result is a new drive to add more value to its stream of intermediates through extracting and marketing petrochemicals, although oil from coal will continue to be Sasol's major business.

According to Kruger, the company's synfuels operations "provide an economic platform covering a high proportion of costs." Take ethylene, for example: "It is far cheaper to extract ethylene from the synthetic process stream, as Sasol already does, than to build a cracking plant to produce ethylene from components of crude oil such as naphtha."

The company is currently investigating projects totaling some $550 million, "the majority of which is earmarked for high-value chemical production," says a Sasol official, and the company expects to spend the money over the next three to five years. Current projects to fuel Sasol's expansion in downstream markets include acrylonitrile and acrylic fibers; alkylamines for explosives via a joint venture with Sentrachem; α-olefins, particularly hexene-1 and pentene-1; and Fischer-Tropsch hydrocarbon waxes.

Among the possible new areas are acetic acid via acid by-product recovered from its Synthol reaction. Sasol believes it has worked out a solvent system to remove the acetic acid, present at less than 1% in the waste stream. The company has built a pilot plant to develop the technology further and hopes to decide on commercialization by the end of 1994.

Sasol at a glance

Headquarters: Johannesburg

Sales: $2.23 billion in 1993 (fiscal year ended June 30, 1993), of which about $335 million was in chemicals

Net profits: $353 million in 1993

Chemical operating profit: $62 million in 1993

Major divisions: Established as wholly owned subsidiaries, operating at arms' length

Sasol Synthetic Fuels—Owns and operates two coal gasification plants, at Secunda, to produce synthetic fuel

Sasol Oil—Controls output from Natref refinery at Sasolburg, plus purchased synthetic fuels; supplies 50% of total South African market for gasoline and other motor fuels

Sasol Mining—Produces 33.4 million metric tons of coal per year from mines at Secunda and 6.8 million metric tons from mines at Sasolburg

Sasol Technology—Provides in-house R&D engineering, process technology, and technology transfer

Sasol Chemical Industries—Owns and operates Sasolburg chemical products complex and other plants; products include waxes, solvents, α-olefins, fertilizers, mining explosives, and candles; joint ventures established in monomers and polymers, in acrylic fibers, and in alkylamines

fields off Mossel Bay on the southern cape coast.

Development of natural gas fields in southern Africa is ongoing, however, both on land and offshore. For example, in April, Sasol and Empresa Nacional de Hidrocarbonetos de Mocambique (ENH), which are jointly promoting the Mozambique-South African Pande gas project, announced that they had approached a number of gas pipeline companies to determine their interest in the project. They indicated that the potential participant will be selected near the end of this year.

Samples show that the gas in the field is dry—high in methane with no sulfur. Eleven exploration wells have been drilled so far, yielding indicated reserves of 2.4 trillion cu ft, of which 1.7 trillion cu ft should be recoverable. South Africa is one of the world's largest economies without access to major supplies of natural gas.

To put the find in context, according to the British Petroleum Statistical Review of World Energy, Algeria's proven reserves are 128 trillion cu ft; Libya's are 45.8 trillion cu ft; Nigeria's, 120 trillion cu ft; and Gabon's, 0.5 trillion cu ft.

Geologists are currently conducting a seismic survey off the Namibian coast, and another off Mossel Bay. All drilling in South African waters up to now has been by the government agency SOEKOR. But that is changing, believes Godfrey Needham, towage and salvage manager for specialty marine services company Pentow Marine, Cape Town, with the possibility that concessions will be opened to outsiders. Namibia has already done that, he points out, and has already received inquiries from oil companies such as Norsk Hydro and Chevron. If exploration is done by private-sector organizations, the sense is that it will be done more efficiently and more thoroughly.

Meanwhile, Sasol is working to expand its businesses internationally. For example, it is seeking the opportunity to license or sell technology to regions with low-cost natural gas reserves—into the Middle East and Southeast Asia, for example. And it is working to interest China—the other major coal-dependent country in the world—in its coal gasification technology.

Sasol's ethylene supplies are now part of Polifin, the 60-40 joint venture with AECI. "Sasol has a contractual commitment to supply all of its raw C_2 and C_3 compounds to its 60% subsidiary Polifin. Polifin owns the plants for cracking and purifying these streams," explains Derek Lake, Polifin's business optimization manager.

The sight of all of Sasol's ethylene going into the hands of a competing polymers producer raised protests from Safripol—a joint venture to produce various polymers—and its two owners, Sentrachem and Hoechst South Africa, to the country's Competition Board. They argued that there would be a concentration of suppliers and were concerned over source of supply.

"There was indeed intervention by the Competition Board in the formation of the Polifin joint venture," says Lake. "Sentrachem claimed that Polifin would result in a reduction in competition. This is not true, as South Africa still has the same number of low-density polyethylene, linear low-density polyethylene, high-density polyethylene, polypropylene, and polyvinyl chloride producers that existed before the joint venture was formed." Sentrachem further claimed that it would be disadvantaged on ethylene and propylene supply, opposite internal consumers within Polifin.

The Competition Board ruled in favor of Polifin, provided that Safripol would not be disadvantaged. "Polifin has nearly completed contractual negotiations with Safripol for ethylene and propylene supply," Lake adds. "The ethylene contract is probably more favorable than the one that Sasol was planning to renegotiate with Safripol before the advent of Polifin, and therefore Safripol is not disadvantaged. Safripol imports propylene and also purchases a quantity from Polifin. The Polifin pricing will be set to match Sentrachem's alternative price. Polifin has almost completed the propylene supply contractual negotiations."

Students at Sentravision Bridging School improve their math and science skills.

The ethylene supply situation appears to be under control now, but there is widespread concern that several years from now ethylene will be in short supply unless Sasol, or another producer, decides to invest in more capacity, probably by the end of the decade. However, most analysts agree that the South African market is too small for major petrochemical projects.

Less-than-expected gas reserves of Mossgas rule out the idea of a gas cracker at Mossel Bay based on locally available gas, according to Sentrachem's Job. "In the long term, South Africa will need a new ethylene source, and Sentrachem will continue to explore opportunities toward this goal, but at a lower activity level," he says in the company's 1993 annual report.

"South Africa is running out of ethylene," Job emphasizes. "That begs the question: Where and how to get more. A cracker? We don't want to just stop polyethylene production because we ran out of ethylene. But crackers are huge investments. You start to think of partnerships, the Republic of South Africa Inc., different ways you can compete internationally. In the late 1980s, the petrochemical world was booming, but [capacity utilization] is currently low. I am not sure what the answer will be."

Pollution and coal dependence

Until South Africa gains adequate supplies of natural gas, enough to fuel heating and cooking as well as petrochemicals, the country will continue to rely on coal. According to the BP energy review, some 78% of South Africa's primary energy comes from coal. Only China is close to that dependence, with 76%.

And given the South African topography, climate, and growing population around metropolitan centers, the coal burning produces the most noticeable environmental effects: a distinct brimstone smell that accompanies the smog around Johannesburg, in particular, in winter mornings and evenings.

"The new government has a million top priorities," comments Sentrachem's Lovell. "It won't do all it wants to do without all sorts of help—perhaps from a wealth tax, and so on. But how much of that will be earmarked for the environment? I would surmise a very limited amount.

"Where there is no electrification, people are still burning solid fuels. You won't solve that pall over the cities until you solve electrification, for example. It won't happen overnight.

"ANC policy has been calling for a much more disciplined environmental approach," Lovell adds. "We have set standards of emission control that we think are right and which in many areas are much tighter than legal requirements. We are doing things to satisfy the public. The public's perception is what counts."

Hoechst's Traub holds similar views. If nothing else, he says, the pressure is growing because of television and the mass media. For example, South African television news programs have been reporting on the consequences of exposure to mercury and other such hazards.

Mercury industrial waste, for treatment at the Thor Chemicals plant near

C&EN staff photo

Sander: learning to be competitive

Durban, has become an international cause célèbre. According to the International Federation of Chemical, Energy & General Workers' Unions (ICEF), in February 1994 a shipment from a polyvinyl chloride (PVC) plant just outside Baton Rouge, La., was due to arrive in South Africa but was recalled at the last minute by the U.S. shipper, Borden, which uses mercury chloride catalyst to produce PVC by the acetylene hydrochlorination process.

The Thor plant, ICEF says, is well known to the international community "because of its atrocious record of workplace safety. Two workers have died at the plant, and 15 have suffered severe health problems." The company is currently involved in legal proceedings on 42 separate counts, with its top officers charged with culpable homicide. Other charges include negligence and failure to meet a number of statutory requirements.

Job: more active in world markets

"There are so many other obvious problems, it may be difficult to raise the environment to as high a profile as in Europe or in the U.S.," agrees AECI's Sander. "But, too imperfectly, we have had a drive to keep our standards up with the rest of the world. The really horrible environmental problems we haven't had—we have no Rhine River to pollute, for example. Our worst problem is dust, for example, from the older steel processes.

"But if we want to play in the world game, we have to play by those rules. We've looked hard over the past five years," he says, at the company's products and processes. He cites the case of chlorofluorocarbons (CFCs) and the Montreal Protocol on Substances That Deplete the Ozone Layer. "It gave us an opportunity to take actions. But it was also a chance to look at our role in the environment as a whole. It is difficult to say, 'I'm going to change over from making CFCs' without filling in the rest of the sentence, 'and also do . . .' "

Responsible Care program

That kind of corporate soul-searching also opened the doors to the Responsible Care program that the South African chemical industry has just adopted. Says Sentrachem's Lovell, "Our Responsible Care initiative had nothing to do with the new South Africa, but it all came together in the nick of time."

Responsible Care has had an incredible impact on the chemical industry around the world since its inception in Canada in 1985. For the industry in South Africa, it even helped spur the formation about a year ago of a new trade organization, based in Johannesburg, through expansion and joining of more limited groups.

In May, at a seminar sponsored by the new group—the Chemical & Allied Industries Association (CAIA)—the circle was completed. The seminar launched the South African chemical industry onto a committed course to join the worldwide Responsible Care program.

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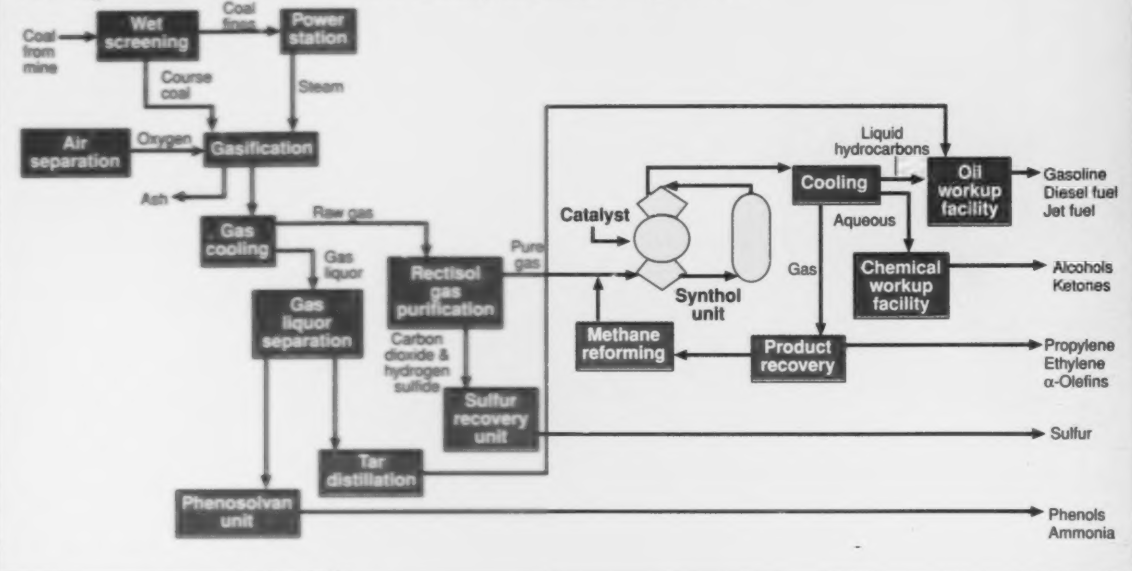
Sasol process converts coal to a variety of chemical products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Steam
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Ash
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Gas liquor separation
Rectisol gas purification
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Catalyst
Synthol unit
Methane reforming
Liquid hydrocarbons
Cooling
Aqueous
Gas
Oil workup facility
Chemical workup facility
Product recovery
Gasoline
Diesel fuel
Jet fuel
Alcohols
Ketones
Propylene
Ethylene
α-Olefins
Sulfur
Phenols
Ammonia

persuasion, have brought 20 large- and medium-sized South African chemical companies to sign onto Responsible Care as of the middle of July. And many smaller firms will sign up in the near future, predicts Peter Hart, Sentrachem's general manager for health, safety, and the environment, who has been temporarily posted to CAIA to guide its program.

"For the chemical industry [in South Africa], Responsible Care was the right decision," Dietlof Maré, of Shell Oil, and chairman of CAIA, told the seminar in May. "But what about the allied industries? What about, for example, packaging, printing, and chemicals transportation? Our attempt was to bring those industries into the fold of CAIA."

The South African industry's move into Responsible Care brought it firmly into league with the rest of the industrial world, says Louis Jourdan, senior director for technical affairs for CEFIC. Brussels-based CEFIC, as a member of the International Council of Chemical Associations (ICCA), has been allocated sponsorship for Responsible Care development in Africa, as the U.S. has for South America, and Japan and Australia have for the Far East.

He makes yet another point with Responsible Care throughout the world: "Even if [Responsible Care] is a basic entity, it has to be adapted to local and national conditions for specifics. For example, it must fit the legislative framework, public opinion, the culture of companies, and the power of each national association."

According to Sentrachem's Hart: "For signing, it is good to catch the chief executives of the corporations, but we also are encouraging subsidiaries to sign on in their own right, too. We haven't really developed a strategy yet for the really small companies. We will have to monitor what happens over the course of the next year or so, to see what is needed."

Jourdan adds: "You want to get as many companies as possible on board, but the emphasis is on the quality of the response. Nothing is worse than having a company sign on and then not implement Responsible Care."

Additionally, "Dialog with communities and the public is one of the primary things that is different from what we have done in the past," says Hart. CAIA has established a public advisory panel, and companies are being encouraged to communicate at the local level, as well—at factories and storage depots, along transport routes, and so on—"where the action is."

Communication includes a worker's right to know, contends Barry Kistnasamy, who is an environmental health specialist and lecturer at Natal University in South Africa's Natal Province and a health policy adviser to the ANC. The right to know is a critical aspect of new occupational health and safety legislation, he says. From it follows the right of a worker to participate or to refuse dangerous work; "trade unions are lobbying very hard to get this put into legislation."

As Kistnasamy sees it, the new legislation is the latest stage in an evolutionary process in occupational health that began with laissez-faire in the 19th century. He cites the currently unfolding court case against mercury processor Thor Chemicals in Pietermaritzburg, Natal, as a case that is expected to set precedents in terms of the personal liability of corporate executives.

John Mills, who recently retired as administrative manager at AECI's production complex at Umbogintwini, near Durban, is now a consultant to AECI and is responsible for the Community Accident Emergency Response (CAER) program at the plant.

This program was inaugurated following several industrial accidents in 1993: In March 1993, chlorine gas was emitted from another company's factory in a Durban suburb, and people needed treatment. Shortly after that, two releases occurred from AECI's Umbogintwini plant. As one of the country's premier firms, AECI was given such rough treatment by the press and media that management brought in a team of outside experts to conduct a plant audit, which was finished in June 1993. The verdict: The plant was intrinsically safe but needed about a dozen specific measures to upgrade it to international standards.

The CAER team was given the task of reviewing emergency procedures and improving communication with the public. In fact, it eventually was told to extend its work from the chlorine operations to all those at the complex.

"We started to think of the worst possible accident we could have, for example, considering wind speed, topography, and so on," Mills says. "We wanted to work out what the local community residents should do." Early on, it was realized that to be able to give immediate warning in the event of imminent hazard, the company had to design a suitable audio alarm and public address system, which it is now working on.

The exercise also led to AECI's developing a commitment charter to the community, which the company's top executives signed on May 4 with community leaders, detailing the obligations the company accepted to be a good, responsible member of the community. "The signing of the Umbogintwini charter represents a giant step into the modern world," said company chairman Sander at the signing of the charter.

Such consultation and discussion are becoming the norm in the new South Africa, says David Baldwin, technical director of Waste-Tech, a company specializing in handling both routine and hazardous wastes. Speaking at the May seminar, he detailed just what happens when a company doesn't consult, using his company as an example of one caught by changing standards.

In 1986, Waste-Tech began looking for a replacement for its hazardous waste landfill near Johannesburg, he says. The Johannesburg region houses most of the country's chemical industry.

It found a site that would serve Waste-Tech's needs and could be made to address any conditions of the various authorities. Purchase was permitted under the authority of the Water Affairs Environmental Conservation Act of 1970. Construction started early in 1993.

At the time of the purchase, approval by local authorities was considered to be community approval as well. But, Baldwin comments, "by 1990, people were beginning to expect to be asked. And there were changes—squatters, homes, some light industry, and a new community no more than 500 yards from our site."

The municipality began to back off; they didn't want to make any decisions, Baldwin figures. "And we had trouble finding who actually represented the communities that had sprung up."

Now, after years of planning and nearly $3 million of capital investment, the project is dead, he says.

Community acceptance, added another seminar participant, is extremely important for new plants. Petro Terblanche, a consultant with CSIR Environmental Services notes: "There are two completely different situations if you are dealing with an existing plant or a new one. An existing factory—although you might not have been or be able to wish it away, and although there might be environmental concerns—is completely different from when an operation is going to begin." Then, she suggests, gaining public acceptance and trust "is 10 times harder."

Moreover, added Kistnasamy, "There will be lots more pressure from the previously shut-out communities to interact with companies. We also need training for people in community participation—in how to be effective community representatives."

From Responsible Care programs just taking shape to new initiatives emphasizing world-scale operations and trade, South Africa's chemical industry clearly faces numerous challenges. Sentrachem's Job summarizes the attitude of many executives in the country's chemical industry when he says: "Looking ahead, we are going to become more active in world markets—either through exports or through the formation of alliances, mergers, and [other agreements] in selected areas outside South Africa. The world is going to see more of us."

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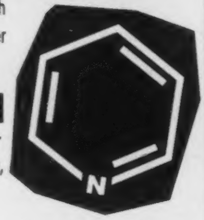

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CIRCLE 6 ON READER SERVICE CARD

Biotechnology firms show mixed performance

In the first half of 1994, biotechnology companies again were all over the map with their financial results. The already prosperous larger companies reported further growth in revenues but a mixed earnings performance. At the same time, smaller companies posted increased revenues but continued to stack up sizable losses.

Only four of 20 companies polled by C&EN reported net earnings for the first half of 1994, and all four had double-digit profit margins. The industry leader is Amgen, with net earnings of $201 million, up 6% from the same period in 1993. Amgen's revenues increased 19% to $779 million. Nearly all of the Thousand Oaks, Calif.-based company's revenues are from sales of its two leading biopharmaceutical products, the white blood cell stimulant Neupogen and the red blood cell stimulant Epogen.

Following Amgen in second place is Genentech, based in South San Francisco. The first half of 1994 was a tremendous comeback period for Genentech. The company posted revenues of $394 million, up 22% from the same period in 1993. Net earnings jumped 192% to $72.2 million, attributed to keeping costs level while increasing sales of human growth hormones, the anti-blood-clotting agent tissue plasminogen activator γ-interferon, and the cystic fibrosis drug Pulmozyme.

Genzyme, whose 14% sales increase to $149 million in first-half 1994 ranks it third among the biotechnology firms polled, reported a 22% decline in earnings to $17.6 million. However, the Cambridge, Mass.-based company's position remains strong—having received Food & Drug Administration approval for Cerezyme, a recombinant enzyme for treating Gaucher's disease and having expanded its business through acquisitions (C&EN, Aug. 1, page 7).

Biogen was the only other biotech firm to post earnings for the first half of 1994. The company did see an earnings drop of 30% from the same period in 1993, to $11.8 million, largely reflecting a 54% increase in R&D spending to nearly $50 million. Biogen's profit margin remained strong at a very respectable 14.5% as revenues grew 11% to $81.6 million for the Cambridge, Mass.-based firm.

Only a few biotech firms had profits in first-half 1994

$ Millions	Revenues[a]	Earnings	Change from first-half 1993		Profit margin[b]	
			Revenues	Earnings	1993	1994
Amgen	$778.7	$200.9	19%	6%	29.0%	25.8%
Biogen	81.6	11.8	11	–30	23.1	14.5
Cell Genesys	5.5	–6.1	93	nm	def	def
Centocor	31.7	–29.2	10	nm	def	def
CytoTherapeutics	1.7	–7.1	156	nm	def	def
Cytogen	0.6	–13.1	–91	nm	def	def
Genentech	393.8	72.2	22	192	7.7	18.3
Genetics Institute	51.7	–19.6	11	nm	def	def
Genzyme	148.7	17.6	14	–22	17.2	11.8
IDEC Pharmaceuticals	2.8	–10.3	–65	nm	def	def
Immune Response	2.6	–9.9	5	nm	def	def
Immunex	73.5	–20.1	na	na	na	def
Isis Pharmaceuticals	8.9	–6.8	49	nm	def	def
Repligen	11.3	–10.7	–17	nm	def	def
Ribi ImmunoChem	2.4	–1.6	52	nm	def	def
Telios Pharmaceuticals	0.9	–11.8	–6	nm	def	def
U.S. Bioscience	4.2	–12.9	–27	nm	def	def
Vertex Pharmaceuticals	10.4	–8.8	67	nm	def	def
Vestar	21.1	–3.1	16	nm	3.0	def
Xoma	1.6	–15.5	256	nm	def	def

a Includes product sales, contract research, royalty, and interest revenues for first six months of calendar year. **b** After-tax income as percentage of sales. **def** = deficit. **nm** = not meaningful. **na** = not available.

Other companies, such as Genetics Institute, Immunex, and Centocor, continue to report sizable revenues but have not yet turned the corner to profitability. Cambridge, Mass.-based Genetics Institute's revenues were up 11% to $51.7 million, largely because of increased product sales and royalties for its first proprietary product, the antihemophilia blood-clotting factor VIII.

Similarly, Centocor's revenues increased 10% in the first half of 1994. The company has been working to cut costs and has succeeded in reducing its net loss in the first half of this year to $29.2 million from $42.1 million in the first-half of 1993, excluding special charges in both years. Having stopped development and marketing of its leading antisepsis product, the Malvern, Pa.-based company is making progress with three other products: an anti-blood-clotting drug, a colorectal cancer drug, and an anti-inflammatory agent.

For the first six months of 1994, Seattle-based Immunex reported a net loss of $20.1 million on revenues of $73.5 million. No comparison was made to the year-earlier period, because the company merged with Lederle Laboratories' oncology business on June 1, 1993. Quarterly product sales of Immunex's white blood cell stimulant, Leukine, have remained level, at about $11 million. The company is now focusing on increasing market share, as well as on reducing expenses and testing new anticancer agents.

The gap between biotechnology companies becomes more and more apparent with each passing quarter. Whereas Amgen's tremendous revenues come largely from product sales, many other less successful companies have only a few million dollars in revenues, with the majority of it coming from contract R&D funding. Large decreases in revenues for the smaller companies often occur when a funded project is completed or canceled. Large increases generally reflect changes from very low levels in the previous year.

Cytogen's 91% decrease in revenues is the result of having not received license or contract revenues from Cyto-Rad, an R&D company it formed in early 1992 (C&EN, June 13, page 34). Cytogen and other companies are facing rapidly dwindling cash reserves with which to fund R&D and business operations.

Ann Thayer

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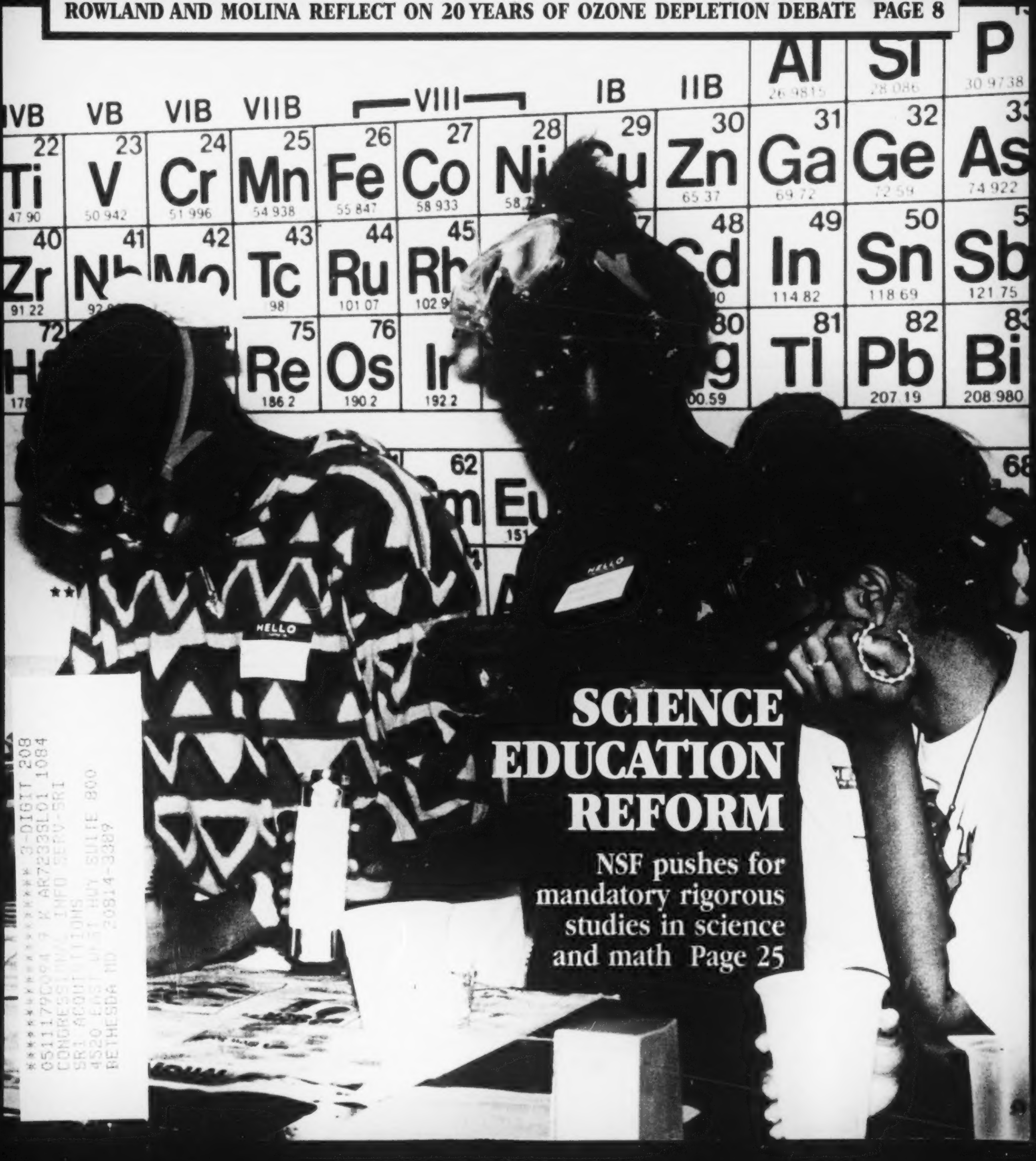
CHEMICAL & ENGINEERING NEWS

C&EN

AUGUST 15, 1994

ROWLAND AND MOLINA REFLECT ON 20 YEARS OF OZONE DEPLETION DEBATE PAGE 8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33 As 74.922
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SCIENCE EDUCATION REFORM

NSF pushes for mandatory rigorous studies in science and math Page 25

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CHEMICAL & ENGINEERING NEWS

C&EN

AUGUST 15, 1994

NEWS OF THE WEEK

- Explosion and fire break out at Exxon's largest U.S. petrochemical plant, causing minor injuries and likely disrupting the already tight ethylene market. **Page 4**
- Caltech chemists develop heterogeneous asymmetric catalyst system that allows production of the anti-inflammatory agent naproxen in 96% enantiomeric excess. **Page 5**
- Clinton Administration is expected to revive the Council on Environmental Quality instead of splitting its functions between EPA and the White House Office of Environmental Policy. **Page 5**
- Terra Industries proposes a $400 million acquisition of Agricultural Minerals & Chemicals Inc. **Page 6**
- Rhône-Poulenc reports disappointing first half but expects increase in net income for 1994 as a result of internal restructuring and improvements in company operations. **Page 6**
- Threat of corrosion of spent nuclear fuel rods stored underwater, leading to possible explosions and release of radioactivity, adds pressure to current U.S.-North Korea talks aimed at halting North Korea's suspected nuclear arms program. **Page 7**

COVER: Chemistry workshop for teenage girls at Institute for Science Education & Science Communication, Columbia College, Chicago. Photo by C&EN's Ernest L. Carpenter

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VIEWPOINT

F. Sherwood Rowland and Mario J. Molina, chemists who led the way in ozone depletion research, reflect on the enormous changes that have taken place over the past two decades in the use of chlorofluorocarbons. **Page 8**

BUSINESS

Major U.S. chemical producers post earnings increase for the fifth straight quarter; drug firms and diversified manufacturers also see a rise in earnings. **Page 18**

GOVERNMENT

U.S. signs controversial Law of the Sea treaty after provisions concerning deep-seabed mining are revised to be more compatible with free-market principles. **Page 32**

SCIENCE/TECHNOLOGY

Factors that underlie linear and nonlinear optical phenomena have been linked together in a simple derivative relationship by a team of U.S. and Belgian scientists. **Page 34**

Dante II performs first robotic observations inside the crater of an active volcano, but a malfunction and foul weather leave the robot stranded near the top of Mount Spurr in Alaska. **Page 36**

New alternative fuels user facility and ethanol plant designed to allow scaleup of biofuel technologies is dedicated at the National Renewable Energy Laboratory in Golden, Colo. **Page 37**

ACS NEWS

September local section meetings feature ACS tour speakers and a selection of topics. **Page 39**

COVER STORY

National Science Foundation aims for nationwide comprehensive reform of science and math education through systemic initiatives backed by millions of dollars. Page 25

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Assistant Managing Editors: Rudy M. Baum, Ernest L. Carpenter, Janice R. Long, Rebecca L. Rawls, William J. Storck
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LETTERS

Fiberglass as a carcinogen

The News of the Week item on the listing of fiberglass as a possible carcinogen by the National Toxicology Program (C&EN, July 11, page 6) incorrectly states that no federal regulations come into play because of the NTP listing. The Occupational Safety & Health Administration's (OSHA) Hazard Communication Standard (29CFR1910.1200) requires that material safety data sheets (MSDS) and labels show that any substance listed as a carcinogen by the International Agency for Research on Cancer (IARC) or in NTP's annual report on carcinogens, or by OSHA, must be designated as a carcinogen. If there is as much as 0.1% of the listed material present in a mixture, then the mixture must be designated as a carcinogen on the MSDS and label. Several states also use IARC and/or NTP as trigger mechanisms in their right-to-know regulations.

It may be true, as Department of Health & Human Services Secretary Donna E. Shalala writes, that "the listing of a substance in the annual report does not establish that any substance presents a risk to persons in their daily lives." The same may be said of an IARC listing; however, the facts don't seem to interfere with the authors of regulations. Mere listing is sufficient to trigger federal and state regulations.

The next time you dig a hole, plant a vegetable, play golf, or go to the beach, consider that IARC has listed crystalline silica (sand) as a carcinogen, and NTP has listed respirable crystalline silica (sand) as a carcinogen—and look out for the coming "risk assessments."

Donald H. Weinblatt
Highland Park, Ill.

Volatile compound removal

The article by Joseph Haggin titled "Catalytic Oxidation Process Cleans Volatile Organics From Exhaust" (C&EN, June 27, page 42) describes three thermal techniques: regenerative, recuperative, and catalytic. There is a fourth technique for removing volatile organic compounds (VOCs) that is also catalytic, at least in part, through enzyme activity in assimilation and dissimilation.

Biofiltration, which is widely practiced in Europe, is now "catching on" in the U.S. in several versions for control of VOCs and odor. The several types of biofilters include biomass beds of mixtures of compost, inert bulking media, nutrients, neutralizing agents, and sometimes activated carbon; open topsoil beds; and biofilm on packed beds supplied with nutrients.

These techniques are especially useful for emissions at ambient temperature and concentrations up to 1,000 or 1,500 ppm by volume. They are most economical in capital, operating, and maintenance costs and they will be increasingly relied on for control of many VOCs.

A. B. Mindler
International Hydronics Corp.
Rocky Hill, N.J.

'Innovative' EPA?

The July 25 issue of C&EN (page 9) announces the Environmental Protection Agency's plan to change its emphasis from individual chemicals to industries. How creative! Except that when EPA was formed in 1971, that was the approach in EPA's Office of Research & Development, where I worked. The only difference was that we didn't need an assistant administrator for each industry. Individuals or branches simply were devoted to one or more industries, learned the manufacturing and environmental technology, developed a rapport with the firms and associations, and worked together to identify and solve the industry's environmental problems.

Promising research ideas that needed development were funded by cooperative grants from the industry associations and the EPA Office of R&D—and were often approved in weeks or even days.

Pollution prevention? It hadn't been invented yet, but that didn't keep us from devising solutions that recovered chemicals, reused water and other solvents, reclaimed heat or energy, or whatever seemed to be cost-effective. Did we solve all the problems? Did we get total cooperation? Were all our projects successful? Obviously not, but great progress was made during the decade toward eliminating significant environmental problems.

As with EPA Administrator Carol Browner's "innovative" new approach, I shake my head at many of today's "innovative" technologies—carbon adsorption, reverse osmosis, UV/ozone, sulfide precipitation of metals, and so on—all of which were already in use or developed during the seventies. Many of the same technologies are still being marketed today—with minor changes—as "research," often by the same firms.

Herb Skovronek
Morris Plains, N.J.

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Chemical Companies' Earnings Improve For Fifth Consecutive Quarter

William J. Storck,
C&EN Northeast News Bureau

Chemical companies posted more earnings increases in this year's second quarter. Results released last month show that chemical companies' earnings grew for the fifth straight three-month period and were up at double-digit rates for the third consecutive quarter.

Results also improved for pharmaceutical firms and diversified companies that produce significant amounts of chemical products. As a group, only oil companies that produce chemicals had lower earnings in the second quarter than they did in the same period a year earlier; however, the decline for most of these companies came in their oil operations, with improvement in chemicals.

For 30 major chemical companies regularly surveyed by C&EN, earnings from continuing operations, excluding significant nonrecurring and extraordinary items, rose an average of 28% over last year's second quarter to a combined $1.59 billion. Combined sales increased about 5% to $21.3 billion. The result was an increase in the aggregate profit margin for the group to 7.5% from 6.1% in the same period a year earlier.

For the first half of this year, earnings for the same 30 companies rose 24% to about $2.84 billion, and sales increased 5% to $41.1 billion. The average profit margin for the group was 6.9%, up from 5.8% in the first half of 1993.

For other producers of chemicals, earnings for 10 pharmaceutical companies increased 29% for the quarter to $3.29 billion on a 12% sales increase to $20.5 billion. That provided a profit margin of 16.0%, up from 13.9% in second-quarter 1993. For the half, earnings

Chemical industry leaders for the second quarter . . .

Sales				Earnings[a]			Profitability		
Rank 1994		$ Millions	Rank 1993		$ Millions	Rank 1993		Earnings as % of sales	Rank 1993
1	Dow Chemical	$4,934.0	1	Monsanto	$258.0	2	International Flavors	18.8%	1
2	Monsanto	2,269.0	2	Dow Chemical	251.0	1	Great Lakes Chemical	12.9	2
3	W. R. Grace	1,236.9	4	Rohm and Haas	95.0	6	Monsanto	11.4	8
4	Union Carbide	1,177.0	3	Eastman Chemical	83.0	3	Loctite	11.4	3
5	Eastman Chemical	1,047.0	5	Union Carbide	73.0	11	Ethyl	11.0	7
6	Rohm and Haas	944.0	6	Arco Chemical	68.0	10	Betz Laboratories	10.5	3
7	Air Products	868.4	7	Great Lakes Chemical	67.7	5	Crompton & Knowles	10.4	6
8	Arco Chemical	824.0	8	Air Products	65.8	4	Lubrizol	10.1	10
9	Morton International	730.8	12	W. R. Grace	65.7	9	Rohm and Haas	10.1	13
10	Olin	708.1	10	International Flavors	64.9	7	Georgia Gulf	9.6	17

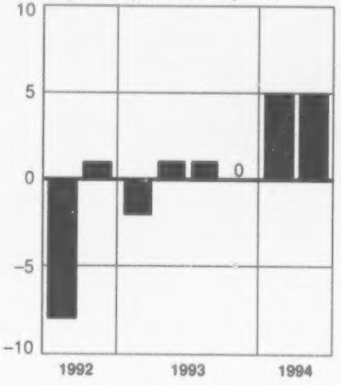
. . . and for the first half of 1994

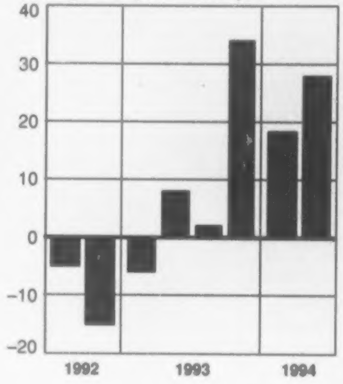
Sales				Earnings[a]			Profitability		
Rank 1994		$ Millions	Rank 1993		$ Millions	Rank 1993		Earnings as % of sales	Rank 1993
1	Dow Chemical	$9,475.0	1	Monsanto	$452.0	1	International Flavors	18.5%	1
2	Monsanto	4,270.0	2	Dow Chemical	424.0	2	Great Lakes Chemical	13.8	2
3	W. R. Grace	2,313.7	4	Rohm and Haas	162.0	6	Loctite	11.4	3
4	Union Carbide	2,303.0	3	Eastman Chemical	139.0	5	Betz Laboratories	10.6	4
5	Eastman Chemical	2,030.0	5	Air Products	138.9	3	Monsanto	10.6	10
6	Rohm and Haas	1,800.0	6	Union Carbide	136.0	12	Crompton & Knowles	10.0	6
7	Air Products	1,727.0	7	Great Lakes Chemical	134.6	4	Nalco Chemical	9.7	5
8	Arco Chemical	1,581.0	8	Morton International	129.9	11	Lubrizol	9.5	8
9	Morton International	1,539.1	10	International Flavors	123.9	7	Rohm and Haas	9.0	11
10	Hercules	1,386.0	9	Hercules	117.0	9	Ethyl	8.7	7

Note: Based on 30 chemical companies listed on page 20 [a] After taxes.

Chemical industry 1994 second-quarter results

- **Sales increased 5%**
- **Earnings were up 28%**
- **Profit margins hit 7.5%**
- **Production rose 3.0%**
- **Prices increased 1.3%**


Sales
% change from year-earlier quarter


Earnings
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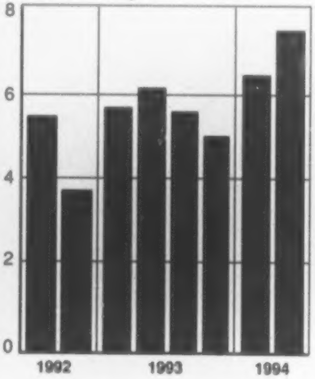
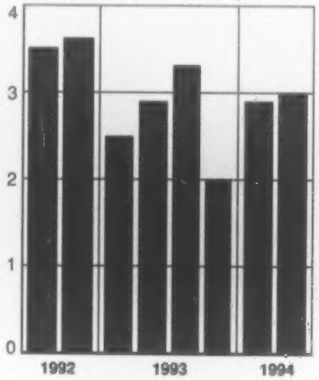
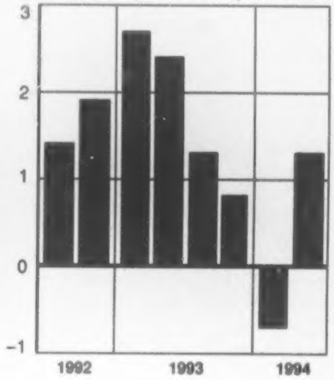

Profit margin
After-tax earnings as % of sales


Production
% change from year-earlier quarter


Prices
% change from year-earlier quarter

Note: All sales, earnings, and profit-margin data are based on 30 chemical companies listed on page 20.

were up 15% to $6.74 billion on an 11% sales increase to $40.6 billion. Profitability for the half improved to 16.6% from 16.0% a year earlier.

For 10 diversified companies, earnings soared 32% in the quarter to $1.70 billion, on a 7% sales increase to $22.1 billion. Profit margin for the firms hit 7.7%, compared with 6.2% a year earlier. For the first half, earnings increased 27% to $3.05 billion on a 5% sales increase to $42.3 billion. As a result, the profit margin rose to 7.2% from 6.0% in first-half 1993.

The 11 oil companies surveyed by C&EN suffered, however, with earnings declining 29% in the second quarter to $2.48 billion on a 2% decrease in sales to $78.5 billion. This caused the aggregate profit margin for the group to fall to 3.2% from $4.3% a year earlier. For the first half, earnings dropped 17% to $5.43 billion while sales declined 3% to $151 billion. Profitability fell to 3.6% from 4.2% a year earlier.

Most of the damage to oil companies' earnings in the second quarter, however, came from the oil side of the business. Chemical results actually improved at many of the firms. For instance, Mobil's chemical earnings of $39 million were three times their value in second-quarter 1993. Shell Oil's chemical earnings, excluding nonrecurring items, improved 169% to $94 million, and Exxon's earnings from chemical operations were up 121% to $190 million for the second quarter.

The chemical industry in the second quarter this year continued to benefit from the improving U.S. economy and also started to get some help from slowly rebounding economies elsewhere in the world.

Major end-use markets continued to improve for chemicals as finances in the automobile and housing sectors of the economy improved once again. And even agriculture, which has been slow off the mark in the economic recovery, showed some improvement in

Major chemical companies increased earnings 28% on 5% sales increase in second quarter

	SECOND-QUARTER 1994						FIRST-HALF 1994			
	Sales	Earnings[a]	Change from 1993		Profit margin[b]		Sales	Earnings[a]	Change from 1993	
	($ millions)		Sales	Earnings	1994	1993	($ millions)		Sales	Earnings
Air Products	$ 868.4	$ 65.8	5%	–7%	7.6%	8.6%	$ 1,727.0	$ 138.9	4%	–5%
Albemarle	269.9	15.3	19	278	5.7	1.8	511.7	25.4	16	171
Arco Chemical	824.0	68.0	3	45	8.3	5.9	1,581.0	113.0	1	14
Betz Laboratories	179.7	18.9	5	1	10.5	11.0	352.6	37.4	4	–2
Cabot	428.8	22.0	2	20	5.1	4.4	863.7	44.3	5	37
Crompton & Knowles	154.5	16.1	5	3	10.4	10.6	288.0	28.9	2	3
Dow Chemical	4,934.0	251.0	2	22	5.1	4.3	9,475.0	424.0	3	27
Eastman Chemical	1,047.0	83.0	3	11	7.9	7.4	2,030.0	139.0	4	4
Ethyl	276.1	30.4	3	13	11.0	10.0	510.1	44.4	–2	–7
First Mississippi	149.4	8.9	25	440	6.0	1.4	279.0	13.8	25	768
H. B. Fuller	272.4	9.3	10	6	3.4	3.5	514.9	13.3	8	14
Geon	284.5	12.8	16	392	4.5	1.1	545.8	19.8	16	nm
Georgia Gulf	208.2	20.0	7	74	9.6	5.9	401.1	32.7	6	51
W. R. Grace	1,236.9	65.7	13	22	5.3	4.9	2,313.7	103.9	11	21
Great Lakes Chemical	525.9	67.7	14	–3	12.9	15.2	974.6	134.6	9	0
Hercules	706.0	64.6	–1	18	9.2	7.7	1,386.0	117.0	0	19
IMC Fertilizer	435.6	15.2	–3	nm	3.5	def	846.1	20.6	89	nm
International Flavors	345.2	64.9	7	7	18.8	19.0	668.7	123.9	6	6
Loctite	177.8	20.2	12	16	11.4	11.0	337.7	38.5	10	4
Lubrizol	408.5	41.4	4	32	10.1	7.9	809.0	77.2	7	16
Monsanto	2,269.0	258.0	2	29	11.4	9.0	4,270.0	452.0	2	33
Morton International	730.8	58.6	26	60	8.0	6.3	1,539.1	129.9	25	53
Nalco Chemical	352.0	33.1	1	–13	9.4	11.0	688.2	66.9	0	–9
Olin	708.1	27.6	13	93	3.9	2.3	1,313.0	42.9	8	65
Petrolite	90.6	4.3	5	–17	4.8	6.0	182.4	9.7	10	–3
Praxair	645.0	47.0	4	24	7.3	6.1	1,256.0	89.0	3	25
Rohm and Haas	944.0	95.0	7	51	10.1	7.1	1,800.0	162.0	5	34
Stepan	112.3	4.1	2	21	3.6	3.0	219.6	6.1	–2	–24
Union Carbide	1,177.0	73.0	–5	78	6.2	3.3	2,303.0	136.0	–5	64
Witco	565.6	29.2	3	40	5.2	3.8	1,119.0	51.3	1	29
TOTAL	**$21,327.1**	**$1,591.3**	**5%**	**28%**	**7.5%**	**6.1%**	**$41,106.0**	**$2,836.4**	**5%**	**24%**

a After-tax earnings from continuing operations, excluding significant extraordinary and nonrecurring items. b Earnings as a percentage of sales. **nm** = not meaningful. **na** = not available.

the quarter—leading to better results for fertilizer manufacturers.

The result was that production of chemicals and products increased 3.0% for the quarter, and prices, after moving down slightly in the first quarter, rose 1.3% in the second quarter on a year-to-year basis. More telling were government data for large-volume industrial chemicals. Federal Reserve Board data show production of industrial chemicals and synthetic materials increasing 5% in the second quarter. However, according to the Department of Labor, while prices of industrial chemicals continued to decline in the quarter—0.6% from the year-earlier three-month period—in June, they finally moved up 0.8% from 12 months earlier.

In particular, two big polymer markets improved in the quarter. Production of plastics in May, the latest month for which data are available from the Society of the Plastics Industry, was up almost 14% from the year-earlier month, while sales and captive use increased almost 11%. Fibers also showed a healthy increase with shipments up almost 6% in the quarter, according to Fiber Economics Bureau data. In support of these data, Dow Chemical noted that its operating income from plastics increased 117% in the quarter on strong global volume and price increases for polyolefins in North America and polystyrene in Europe.

Government data also show that demand for chemicals increased substantially in the second quarter. According to Commerce Department figures, the value of shipments of chemicals and allied products rose about 7.5% in the second quarter, while shipments value of the industrial chemicals subcategory increased an even greater 8.6%.

Producers continued to cut costs to raise their profit margins during the second quarter. For instance, downsizings of staff continued, according to the Labor Department. In the second quarter, some 23,000 fewer employees worked in the chemicals and allied products industry than did so a year earlier.

Monsanto's chairman and chief executive officer, Richard J. Mahoney, indicates that most of these conditions

FIRST-HALF 1994		12-MONTH RUNNING DATA			
Profit margin[b]		Change from 1993		Profit margin[b]	
1994	1993	Sales	Earnings	1994	1993
8.0%	8.8%	3%	–2%	8.0%	8.4%
5.0	2.1	na	na	na	na
7.1	6.3	2	7	7.4	7.0
10.6	11.2	0	–12	10.1	11.4
5.1	3.9	3	46	4.5	3.2
10.0	9.9	3	9	9.4	8.8
4.5	3.6	–1	25	3.8	3.0
6.8	6.9	2	–13	6.6	7.8
8.7	9.2	na	na	na	na
4.9	0.7	15	387	3.5	0.8
2.6	2.5	6	–11	2.9	3.4
3.6	def	15	nm	2.6	def
8.1	5.7	2	31	6.9	5.4
4.5	4.1	–6	16	5.4	4.4
13.8	15.1	14	7	14.5	15.4
8.4	7.1	0	29	8.3	6.4
2.4	def	61	nm	def	0.7
18.5	18.6	4	4	17.0	17.1
11.4	12.1	5	–11	10.8	12.7
9.5	8.8	6	29	8.4	7.0
10.6	8.2	3	49	7.4	5.2
8.4	6.9	23	42	7.9	6.9
9.7	10.7	0	–2	10.5	10.7
3.3	2.1	7	51	2.3	1.6
5.3	6.0	13	17	5.5	5.4
7.1	5.8	–1	25	6.7	5.3
9.0	7.1	3	5	6.5	6.3
2.8	3.6	–1	–28	2.5	3.4
5.9	3.4	–7	79	5.0	2.6
4.6	3.6	6	44	4.7	3.5
6.9%	5.8%	1%	14%	5.6%	5.2%

def = deficit

prevailed at his company: "Second-quarter and first-half results were driven by continuing worldwide volume gains for our agricultural products, strengthening economic conditions in North America and Europe . . . and across-the-board cost control and productivity measures. We are well on our way to achieving our financial goals," he says.

Along with volume increases, pricing, which seems finally to be turning up, came in for some attention from chemical company executives in the quarter. At Dow Chemical, for example, Enrique C. Falla, the company's executive vice president, says: "Supply is tightening for chlor-alkali products, ethylene, and styrene, resulting in future higher prices for many of our basic and specialty chemicals and plastics. We anticipate that ongoing price increases, leveraged by productivity improvements, will help us maintain our present momentum and lead to further earnings growth through 1994." Falla notes that caustic soda prices were weak compared with a year ago but that they are now rising with significant improvements expected in 1995.

Robert D. Kennedy, Union Carbide's chairman and chief executive officer, says, "Earnings improvement resulted mainly from higher volumes from many of our key products and from higher prices for high and linear low-density polyethylene." However, he notes that prices and margins may come under pressure by year's end as additional ethylene and derivatives capacity comes on-line.

At Geon Co., the large polyvinyl chloride producer spun off from BF Goodrich, chairman and chief executive officer William F. Patient says: "Our aggressive productivity programs are allowing us to capitalize on stronger consumer demand while we drive our costs to lower levels. The strong demand also allowed us to increase prices during the quarter."

However, some companies are still complaining about product pricing. Eastman Chemical notes that physical volume increases in some product areas of its industrial chemical segment were higher than sales increases because of lower prices in the quarter.

DuPont notes lower selling prices in its fibers and polymers sectors as earnings in its chemicals operations declined for the quarter. DuPont, in the second quarter, was the rare company whose oil operations improved while chemicals faltered.

Many of the companies note better results as foreign economies began to emerge from recession. At specialty chemical maker Betz Laboratories, president and chief executive officer William R. Cook says, "Our second-quarter results reflect improving business conditions within the industrial sector of the economy. Our foreign operations had a particularly strong quarter and posted double-digit sales volumes in Canada, the Caribbean, Australia, and throughout most of Europe."

All of PPG Industries' businesses—coatings, glass, and chemicals—recorded volume gains as a result of continued economic expansion in North America and strengthening European markets. Company chairman and chief executive officer Jerry E. Dempsey says, "We believe Europe is now in a sustained recovery, commodity chemical prices have stopped their decline, and we remain optimistic about our business in North America and the Asia-Pacific region."

On the other hand, surfactant manufacturer Stepan's chairman and president, F. Quinn Stepan, says, "The company's Mexican and Canadian opera-

Ground rules for C&EN earnings analysis

C&EN's quarterly report on financial performance of the U.S. chemical industry contains data from the 30 largest U.S. basic chemical companies and from 21 oil and diversified companies, each with more than $200 million in annual chemical sales, plus 10 pharmaceutical companies.

To be included in the table of basic chemical producers, a company must have at least 50% of its sales in chemicals. That is why DuPont, for example, is included in the table of diversified manufacturers.

In referring to chemical sales, C&EN means those chemicals whose molecular composition has been changed in the course of manufacture. Hence, chemical sales include those of traditional categories of basic petrochemicals and inorganics, organic intermediates and inorganic compounds, polymers such as plastics and fibers, and agricultural chemicals and specialty derivatives.

Earnings fell 29% for oil companies but rose 32% for diversified firms and 29% for drug firms

	SECOND-QUARTER 1994						FIRST-HALF 1994					
	Sales	Earnings[a]	Change from 1993		Profit margin[b]		Sales	Earnings[a]	Change from 1993		Profit margin[b]	
	($ millions)		Sales	Earnings	1994	1993	($ millions)		Sales	Earnings	1994	1993
OIL AND GAS COMPANIES												
Amoco	$ 8,035.0	$ 396.0	11%	−19%	4.9%	6.7%	$ 14,800.0	$ 794.0	4%	−10%	5.4%	6.3%
Ashland	2,703.0	44.0	4	−12	1.6	1.9	4,910.0	76.9	−2	17	1.6	1.3
Chevron	8,800.0	262.0	−11	−54	3.0	5.7	17,100.0	686.0	−10	−36	4.0	5.7
Exxon	27,319.0	885.0	−2	−28	3.2	4.4	53,283.0	2,045.0	−3	−15	3.8	4.4
Fina	838.1	13.4	−10	−78	1.6	6.7	1,615.5	38.4	−10	−38	2.4	3.5
Mobil	16,237.0	513.0	0	−1	3.2	3.2	31,292.0	1,048.0	0	4	3.3	3.2
Occidental Petroleum	2,162.0	−19.0	8	nm	def	3.7	4,268.0	−59.0	2	nm	def	3.8
Phillips Petroleum	2,995.0	60.0	−7	−56	2.0	4.2	5,879.0	169.0	−6	−13	2.9	3.1
Shell Oil	5,126.0	257.0	−6	20	5.0	3.9	9,940.0	475.0	−6	18	4.8	3.8
Sun Co.	2,253.0	−1.0	−8	nm	def	1.7	4,320.0	33.0	−9	−57	0.8	1.6
Unocal	2,045.0	65.0	−3	−26	3.2	4.2	3,961.0	127.0	−10	−32	3.2	4.2
TOTAL	$78,513.1	$2,475.4	−2%	−29%	3.2%	4.3%	$151,368.5	$5,433.3	−3%	−17%	3.6%	4.2%
DIVERSIFIED MANUFACTURERS												
AlliedSignal	$ 3,187.0	$ 196.0	4%	17%	6.1%	5.5%	$ 6,173.0	$ 365.0	4%	17%	5.9%	5.3%
DuPont	10,161.0	839.0	6	56	8.3	5.6	19,351.0	1,481.0	4	48	7.7	5.4
Engelhard	633.4	31.9	12	12	5.0	5.1	1,191.1	54.6	13	23	4.6	4.2
Ferro Corp.	300.2	12.0	7	−12	4.0	4.9	583.5	23.3	9	−13	4.0	5.0
FMC	1,053.8	67.3	8	8	6.4	6.4	1,962.1	113.4	4	5	5.8	5.7
Freeport-McMoRan	468.4	13.9	11	395	3.0	0.7	918.0	37.3	27	nm	4.1	def
BF Goodrich	540.5	18.5	19	208	3.4	1.3	1,042.9	23.4	26	nm	2.2	def
3M	3,772.0	343.0	7	4	9.1	9.4	7,404.0	649.0	5	−2	8.8	9.4
PPG Industries	1,619.3	148.1	6	39	9.1	7.0	3,096.2	270.0	4	16	8.7	7.9
Vulcan Materials	326.7	33.7	7	7	10.3	10.3	543.6	28.5	5	−8	5.2	6.0
TOTAL	$22,062.3	$1,703.3	7%	32%	7.7%	6.2%	$42,265.4	$3,045.5	5%	27%	7.2%	6.0%
PHARMACEUTICAL COMPANIES												
Abbott Laboratories	$ 2,204.0	$ 376.6	6%	9%	17.1%	16.7%	$ 4,419.3	$ 742.8	7%	7%	16.8%	16.8%
American Home Products	1,977.9	300.0	4	4	15.2	15.1	4,121.9	715.8	3	4	17.4	17.1
Baxter International	2,316.0	144.0	5	9	6.2	6.0	4,509.0	275.0	6	46	6.1	4.4
Bristol-Myers Squibb	2,970.3	542.0	6	4	18.2	18.6	5,804.2	1,123.0	4	3	19.3	19.7
Eli Lilly	1,678.5	346.6	8	0	20.6	22.2	3.315.5	677.3	6	−6	20.4	23.1
Merck	3,792.0	764.1	47	343	20.2	6.7	7,306.3	1,439.2	48	83	19.7	15.9
Pfizer	1,923.3	257.2	10	23	13.4	12.0	3,906.2	627.9	8	8	16.1	16.1
Schering-Plough	1,190.1	240.7	6	13	20.2	19.0	2,351.7	493.9	6	13	21.0	19.7
Upjohn	891.0	120.1	0	−4	13.5	14.0	1,796.8	254.8	−1	−8	14.2	15.3
Warner Lambert	1,552.2	196.8	7	4	12.7	13.1	3,025.1	387.1	9	4	12.8	13.3
TOTAL	$20,495.3	$3,288.0	12%	29%	16.0%	13.9%	$40,556.0	$6,736.8	11%	15%	16.6%	16.0%

a After-tax earnings from continuing operations, excluding significant extraordinary and nonrecurring items. b After-tax earnings as a percentage of sales. **nm** = not meaningful. **na** = not available. **def**=deficit.

tions and the broad commercial base in the U.S. all showed improvement, while earnings from the European operations continued to reflect competitive pressures."

The results seen in the second quarter and through the first half continue to lend an air of cautious optimism for at least the remainder of 1994 to the chemical industry. At Rohm and Haas, J. Lawrence Wilson, chairman and chief executive officer, strikes the tone for the industry, saying: "Earnings are up—that's good news, but they still are below the levels we feel we need to do well in an industry where competition is becoming more and more fierce. It remains critically important for us to maintain good control of internal costs to become more efficient in meeting customer needs and more productive overall." Wilson does say, however, that the company's 1994 results will be substantially above 1993 earnings and may exceed the company's record performance of $230 million in 1988, "but currency changes and the current upward trend in raw material costs could influence that comparison." ☐

NSF Stakes Millions On Sweeping Reform Of Science, Math Education

■ ***State, urban, and rural systemic initiatives aim to transform entrenched practices and attitudes; critics wary of approach***

Pamela S. Zurer, C&EN Washington

Last May, the National Science Foundation announced the first major awards under its year-old Urban Systemic Initiative (USI). Nine cities, each with large numbers of children living in poverty, will receive $15 million over five years to improve science, mathematics, and technology education. The agency's total commitment could grow to as much as $375 million if the 16 other cities eligible for USI awards eventually win them.

Although big bucks for NSF, the USI awards are relatively small change for the cities, some of which juggle billion-dollar education budgets. Yet NSF expects the USI money to catalyze sweeping changes that ultimately will close the gap in achievement between the impoverished urban school districts' mostly minority students and their white suburban counterparts.

NSF wants the cities to root out the entrenched attitudes and practices that relegate the majority of their students to boring, "dumbed-down" classes where little is expected of them. Instead, the agency envisions educational systems where all children—whether headed for the work force or college—are required to take challenging yet engaging math and science courses every year.

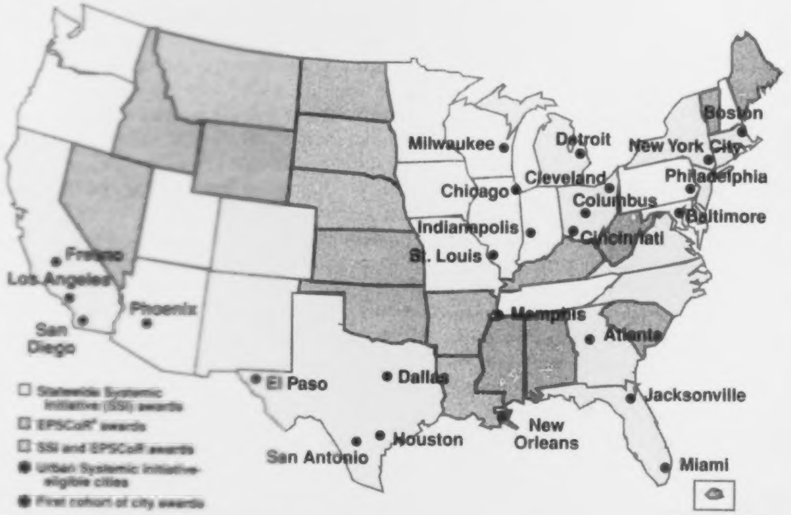
"This program is designed to break rank with the situation in which mathematics and science education has been characterized by low student achievement, minimally demanding courses, and a variety of other less than exemplary developments," said Luther S. Williams, NSF assistant director for education and human resources, when the awards were announced.

"The end result has been graduates who are rarely well prepared for higher education in science, mathematics, or engineering and, more importantly, are ill-prepared for employment of an increasingly technological nature," he continued. "We expect to revise all elements of the status quo."

NSF's strategy for transforming the status quo is through what it calls systemic reform—a comprehensive approach that tackles all components of the educational system at once. The urban initiative, with its special emphasis on improving performance of minority students, is only one element in the ambitious reform effort of NSF's Directorate for Education & Human Resources (EHR). In addition, half of the states are each receiving up to $10 million over five years in the ongoing Statewide Systemic Initiative (SSI). And just getting under way is the Rural Systemic Initiative, directed at improving science education in rural counties with high poverty rates.

Systemic reform means that NSF no longer wants to support isolated, piecemeal projects whose benefits never spread beyond the school or classroom where they were developed. Instead, the agency is trying to get educational establishments to simultaneously implement improved curricula, teacher enhancement programs, innovative testing methods, and policies that support the changes. It is encouraging cooperation among school systems, parents, local business communities, uni-

Systemic initiative awards span much of the country


Boston
Detroit
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Indianapolis
Cincinnati
Fresno
St. Louis
Los Angeles
Memphis
Phoenix
San Diego
Atlanta
El Paso
Dallas
Jacksonville
New Orleans
Houston
San Antonio
Miami
Puerto Rico
☐ Statewide Systemic Initiative (SSI) awards
☐ EPSCoR^a awards
☐ SSI and EPSCoR awards
● Urban Systemic Initiative-eligible cities
● First cohort of city awards

a Experimental Program To Stimulate Competitive Research. **Source:** National Science Foundation versities, and museums. And NSF insists that its partner cities and states set clear goals and demonstrate how they are achieving them.

The education directorate budget of NSF has more than doubled in the 1990s, growing much faster than those of the agency's research directorates. Within EHR, the Office of Systemic Reform has been expanding most rapidly. It commands $110 million this fiscal year, almost 20% of EHR's $570 million budget and as much as the entire directorate received in 1987.

Furthermore, Williams has directed that programs in EHR's other divisions must reinforce systemic reform. For example, programs to help teachers improve their scientific knowledge base now also are designed to get them thinking about how they teach and the different ways students learn. "We no longer let a thousand flowers grow," says Margaret B. Cozzens, director of the elementary, secondary, and informal education division. "We look at the big picture."

For the most part, the cities and states that are the targets of NSF's systemic reform effort welcome both the infusion of funds and the imprimatur of the prestigious agency for their efforts to improve science and math education. But many academic researchers, science educators, and professional society officials, who constitute the NSF education directorate's more traditional clientele, are uneasy about the new thrust.

In the past, the education directorate has funded scientists and science educators to develop courses or work directly with teachers. Now, the systemic initiative awards are going to state and local entities that do not have the same direct connection to science. The political context worries many onlookers.

Only a few of these critics are willing to speak for the record, because almost anyone deeply involved in science education is either funded by NSF or hopes to be. But all express the same fear: The agency is pouring millions of dollars into the same state and local bureaucracies that have neglected the very problems they are now supposedly correcting. Will NSF's funds effect any real change? How can it demonstrate whether the systemic initiatives are working? Will the agency be called on the carpet in a few years, unable to prove that its systemic reform programs have stimulated any improvement?

C&EN staff photos

Danek (left): kids deserve a lot more; Williams (above): revise the status quo

Much of what NSF hopes to accomplish with systemic reform involves changes in policies and attitudes—intangibles that are difficult to measure. Even if some school systems do reform themselves, critics worry that it will be impossible to show that it was NSF's influence that tipped the balance.

Congress has specifically directed EHR to evaluate the effectiveness of its programs. The division of research, evaluation, and dissemination, created in 1992, oversees independent reviews of EHR's programs, evaluating about a third at any one time, according to division director Daryl E. Chubin. Judging the effectiveness of systemic reform is requiring the invention of new kinds of evaluation tools, because systemic reform aims to change not just the educational system but its surrounding environment as well.

So far, Congress has been generally supportive of the systemic reform movement, acknowledging it's still too early to judge whether the systemic initiatives have been a success. The effort even has a cheerleader in Sen. Barbara L. Mikulski (D.-Md.), chairman of the appropriations subcommittee that controls NSF's budget, who speaks passionately of her hopes for USI. And outside government, the systemic effort has other champions who believe the risk is worth the potential rewards.

"Anybody with any sense ought to have the same fears: These initiatives are high risk, but they are potentially high payoff," says Shirley Malcolm, head of the American Association for the Advancement of Science's education and human resources effort, which has its own, much smaller scale systemic reform program. Malcolm, a member of NSF's policy-setting body, the National Science Board, as well as of the President's Committee of Advisers on Science & Technology, is a staunch defender of NSF's systemic reform movement.

"With systemic reform, for the first time we are really trying to address all the critical issues," Malcolm tells C&EN. "People have been saying: 'We need better curricula. The teachers need training. We need good materials.' Yes, yes, and yes! But those are only part of the puzzle. We need to change policy. We need to change the system that doesn't believe all kids can succeed.

"We've got to try," she continues. "Just because we don't know how to do something is no reason not to try to do it. We learn in the process. The risk of doing nothing is much greater than the risk of undertaking some kind of systemic initiative."

Doing nothing, Malcolm says, would perpetuate a system that does not serve all children well in math, science, and technology. Across the country, there is an enormous disparity between minority and white students. NSF reports that three quarters of white eighth graders in the U.S., but only 37% of Hispanic and 26% of black students, perform at or above basic achievement levels in math.

"In my view, the performance gap is the most critical problem in science and mathematics today," says Joseph D. Danek, head of EHR's Office of Systemic Reform. A Ph.D. science educator, Danek has helped create a number of cutting-edge programs in his two decades at NSF. "We can't have millions of students in certain school districts in this country coming out of 12 years of education at a fourth-grade reading level and a third-grade mathematics capability. That's totally irresponsible.

"Those kids deserve a hell of a lot more. They deserve the ability to be able to find a job at some place other than McDonald's, where they don't even have to calculate change. We can't grow the country, can't innovate like that. It's crazy."

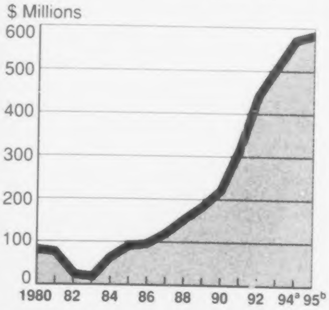
Danek points out that, during the 1980s, NSF's education focus was on the development of Ph.D.s for careers in science and engineering. "People worried about dropouts from the education 'pipeline,' about how to get students to Ph.D.s," he says. For the 95% of students who don't pursue math, science, or engineering as a career, the goal was an appreciation of those seemingly formidable subjects.

But in the past several years, EHR has embraced an important conceptual change that underlies the systemic reform effort. Now the education directorate aims to ensure that all students, not just the best and brightest, are prepared for useful lives in today's technology-oriented world through rigorous study of science and math.

"I don't subscribe to the notion that the role of NSF should be to make provisions for merely acquainting students with science," Williams tells C&EN. "We must move . . . to science and mathematics being as indispensable to what it means to be an educated person as is English.

Malcolm: high risk, high payoff

Education budget more than doubled in 1990s



Note: Data for fiscal years; reflect current composition of Education & Human Resources Directorate. **a** Current plan. **b** Budget request
Source: National Science Foundation

"American students basically have a K–9 [kindergarten through ninth grade] system in mathematics and science education, except for those few rare individuals who are very interested," he notes. "After the ninth grade, there are no requirements for students to actually seriously study science and mathematics."

Instead, students who are not perceived as destined for college take courses such as applied math or general science, which demand little and cover the same ground over and over. In the worst cases, Williams says, students are funneled into remedial courses meant to teach them what they should have learned earlier. Rather than shunting those children out of a system that fails them, he says, "it would be better to change the system."

NSF's education directorate itself has undergone enormous change since what was then called the Directorate for Science & Engineering Education was virtually abolished by the Reagan Administration in spring 1982. It was reestablished a year and a half later after the 1983 report "A Nation at Risk" concluded that the future of the U.S. was threatened by the weak state of U.S. education in general and science education in particular.

By the end of the 1980s, the directorate was commanding close to 10% of NSF's then roughly $2 billion budget. Under the energetic leadership of Bassam Z. Shakhashiri, now professor of chemistry at the University of Wisconsin, Madison, Congress regularly appropriated more money for the directorate than the President requested.

In 1990, outgoing NSF director Erich Bloch reorganized the directorate and replaced Shakhashiri. NSF's programs on women, minorities, and the handicapped were combined with its existing education programs to create the Directorate for Education & Human Resources. Williams, a former president of historically black Atlanta University who had been serving as a senior science adviser to Bloch, was put in charge. EHR today accounts for almost 20% of NSF's fiscal 1994 budget of $3 billion.

According to Danek, the roots of systemic reform can be traced to an older NSF program that was moved into EHR during a later reorganization: the Experimental Program To Stimulate Competitive Research (EPSCoR). That program was begun in the late 1970s to respond to complaints from Congress that a relatively few prestigious research universities continually corner the bulk of federal research funding. EPSCoR aims to help states develop the capacity to compete with Stanford University, Massachusetts Institute of Technology, and the like.

"NSF started what amounts to the first systemic, comprehensive effort to get into a state and see what the problems and issues are," says Danek, who helped create the program. "We ask the states: 'What's your current status? Where do you want to be?' "

Many of the states that have worked with NSF in EPSCoR are now part of the Statewide Systemic Initiative (SSI). Launched in 1990, SSI requires commitments from governors and the states' top education officials to adopt policies, personnel practices, and textbooks and curricula that will lead to lasting change in their science education programs. The states are supposed to work with industry and local communities and at least match NSF's $2 million a year with funds from other sources.

EHR made the first of its five-year SSI awards to 10 states in 1991 and added 10 more states and Puerto Rico in 1992 and another five states in 1993. The awards are not grants but cooperative agreements that can be phased out if the awardees do not perform up to expectations. The state programs are asked to continually evaluate themselves and are monitored regularly by NSF staff and outside experts.

"The whole notion of monitoring progress has to begin the day we make awards," says Williams. "The temptation to start in good faith and not carry through is enormous.

"This is a very different way of doing things than previously. Consider the total amount of money that was spent by colleges and universities, federal agencies, and private foundations on science and engineering and mathematics education over the past 20 years. What's the return? What's the outcome?

"The monies accomplished very little," he says. "But worse, there is no body of evidence to which you can go as a scholar to find explicit explanations as to why it didn't work. The job didn't get done and there's been no effort to explain why."

To change that situation, every proposal that NSF funds under the systemic initiatives sets out goals that get more specific as the five-year award period progresses. The education directorate expects to see change in less tangible areas such as goals, leadership, organization, and community involvement as well as in more concrete aspects like course requirements, teacher training, and student achievement.

"In these systemic reforms you are looking for policy changes that will dictate a whole different set of scenarios," Danek says. "When you say all kids will take science and math for three years, you are saying 'I'm not just going to worry about the best and brightest.' That translates to the fact that you're going to have to figure out how to get teachers to believe that all the kids can [succeed].

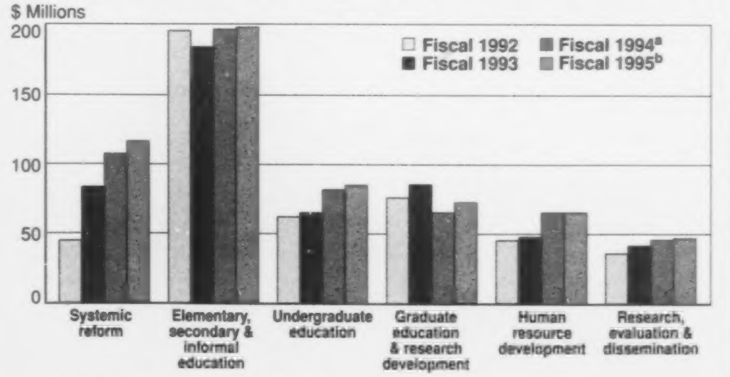
"You are trying to get massive change in beliefs and attitudes and behaviors in people. This is quite different from a research grant."

Danek explains the types of systemwide changes NSF hopes to see the cities and states make: "Can they reduce resistance to change? Have they brought together groups of people who can make a difference? Or it is just the same old organizational structure we've had before with the same people doing the same thing?"

This past winter, EHR sponsored a comprehensive "midpoint" review of the 10 states that were in the first group to win SSI awards. The outside review panel of experts identified concerns in six of the 10 states' programs. A few states are in deep trouble, and one—Rhode Island—has had its funding cut off.

Rhode Island was phased out after receiving $5 million of an expected $9.3 million award. "If you looked at what we got for the $5 million, you would question whether it was a good investment," Danek says. He notes the state had changed project directors three times, and then it was doubtful whether its program would have a significant impact on school improvement.

Systemic reform is fastest growing education division



a Current plan. b Budget request. **Source:** National Science Foundation

The unprecedented termination of such a major project is helping supporters of EHR blunt criticism that the systemic initiatives are becoming entitlement programs. In an April letter to the appropriations subcommittee chaired by Sen. Mikulski, for example, the American Chemical Society opposed NSF's expansion of its systemic reform programs before their effectiveness has been established.

Critics also worry that decisions about which states or cities get the awards are too vulnerable to political influence. However, although Rhode Island's senior Senator, Democrat Claiborne Pell, chairs an important subcommittee with jurisdiction over NSF's education programs, that state's systemic initiative funding was not saved.

"If a state doesn't stick to the agreed plan, it should be terminated," says a staff member of the House Committee on Science, Space & Technology. "It's a healthy sign NSF cut off Rhode Island. There's a danger that when you start something big it will be difficult to turn off because of political pressures."

Rhode Island's plight and the problems other states are facing underscore the difficulty of what the systemic reform initiatives are attempting. Educator Thomas Sachse, who until last month directed California's program and is now with the California Science Project, a statewide teacher development program, remarks: "As one of my colleagues in Florida said, systemic reform is finding out everything that needs to be done and doing it first.

"It's like being a hummingbird: There's a lot of cross-pollination and flitting around. These are extremely ambitious programs. We are trying to connect every part of the system and monitor how things are changing. You need a team mechanism to create a very broad net."

The California SSI program is concentrating its resources on elementary science and middle-school mathematics, with the goal of preparing all students to take college-preparatory-level courses when they reach high school. The state is introducing up-to-date curricula and materials and working with colleges and universities to provide after-school and Saturday training for teachers. About 40% of California's 1,000 middle schools and about 25% of its 4,700 elementary schools are now participating, according to Sachse.

But the obstacles are large. For example, the philosophy underlying systemic education reform includes changing not just what children are taught and how but also how they are evaluated. Tests ideally should measure problem-solving skills and the ability to analyze—not just factual knowledge.

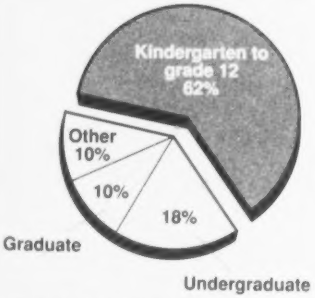
But California's Gov. Pete Wilson recently vetoed the state's controversial new assessment program, which Sachse considers very important to gauging how students are learning under the science education reform initiative. The testing program was sunk by the objections of some parents and conservative groups to what they saw as unsuitable meddling in children's feelings and belief systems—issues not specifically related to science education.

Sachse believes the SSI funds have allowed California to coordinate and assess its science education programs in ways it could not have done without NSF's involvement. But the NSF monies amount to only $2 million a year compared with the state's education budget of $30 billion—an example of what systemic reform's critics see as a major flaw.

"I don't want to be too critical; I'm taking a wait-and-see attitude, but it's unclear how dumping a few million dollars into a state can make that much difference," says Glenn A. Crosby, professor of chemistry and materials science at Washington State University, Pullman, and former chairman of the ACS Society Committee on Education.

Crosby voices the fears of many other onlookers who are more reluctant to speak for the record. NSF's funds, they worry, will be quickly institutionalized, frittered away on cities' and states' large bureaucracies, or spread so thinly they will have little effect.

NSF education programs emphasize precollege level



Fiscal 1994 total = $570 million

Source: National Science Foundation

Aldridge: criminal to limit staff

But EHR officials say the SSI and USI funds are not meant to pay the full bill but rather to push the cities and states in a new direction. "While NSF's several million dollars a year is not inconsequential," Williams says, "NSF is not really funding the total reform of the system. Our monies are designed to catalyze the redirection of the existing monies in the schools."

Danek cites as an example the recent decision by Ramon Cortines, chancellor of New York City public schools, to require that all high-school students take three years of advanced science and math courses. "NSF didn't pay for anything," he points out. "That's a policy change they are making because they accept the fact that under USI they are going to have to deliver students who are competent in science and mathematics at the end of their 12 years of education.

"Is NSF going to pay for the increased cost?" Danek muses. "No way! Cortines is going to have to figure out his own budget."

Although most of the education budgets of big cities are tied up in salaries and benefits, there is flexibility to redirect a significant amount. Both cities and states receive millions of dollars in Department of Education funds, for example, which Williams believes could be put to better use.

"What is it that would justify any of the nine cities to which we have made USI awards employing their resources in the mode they have for the past 20 years?" he asks. "There is nothing to recommend it. Why not try another option for, say, three years?"

In working with the USI cities, EHR has drawn on its experience with the states. EHR staff has tried to spell out exactly what is expected from USI participants and is working even more closely with the cities than it has with the states taking part in SSI. Williams has personally traveled extensively to spread the gospel among mayors, school officials, and local business leaders.

But the directorate's goal of constant interaction, monitoring, and feedback is hampered by lack of staff and funds for travel. To get around the shortages, most EHR program officers work extremely long hours. Because EHR staff members can't visit awardees as often as they believe is necessary, the city and state officials travel to NSF in Arlington, Va., on "reverse site visits."

"I think it's criminal to give an agency like that $600 million for science education and then limit their staff and refuse to provide the necessary travel budget so they can monitor these things," says Bill G. Aldridge, executive director of the National Science Teachers Association. "You can't just sit at a desk and hand out $600 million. If the government later finds out the money is wasted, it will be its own fault."

Williams is keenly aware of his directorate's responsibilities to the taxpayer. "Our Congressional appropriation is an authorization to spend a certain amount of money," he says. "At the end of the fiscal year, you've spent so many dollars and maybe, maybe, something has been accomplished. I am tasked to ask the question if in fact the quality of American science and mathematics education is substantially improved or changed by our efforts."

Indeed, the future of the systemic reform effort depends on demonstrating whether NSF money can make a lasting difference. The answer to that question should become apparent within a few years, after the educational system, Congress, and NSF itself have evaluated the systemic reform movement that has become a larger and larger part of the agency's education directorate. ☐

CHEMICAL & ENGINEERING NEWS

C&EN

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C&EN

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- Crystal structure studies of a hydrolytic catalytic antibody reveal that the antibody's active site has structural similarities with serine proteases—an important class of enzymes. **Page 6**
- American Home Products and American Cyanamid end two weeks of suspense by agreeing on a friendly merger, with AHP paying $9.7 billion, or $101 a share, for Cyanamid. **Page 7**
- German police have seized nuclear materials containing weapons-grade plutonium that may have been smuggled from Russia or other former Soviet republics. **Page 7**
- U.S.-North Korean pact takes a major step toward allaying concern about North Korea's suspected nuclear arms program, but serious questions remain. **Page 8**
- A National Assessment of Educati[illegible] Progress trend report finds substantial gains in precollege science and math proficiency. **Page 8**
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1155—16th St., N.W., Washington, D.C. 20036
Editor: Michael Heylin (202) 872-4501
Managing Editor: Madeleine Jacobs
Assistant Managing Editors: Rudy M. Baum, Ernest L. Carpenter, Janice R. Long, Rebecca L. Rawls, William J. Storck
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LETTERS

What kind of science policy?

In implementing the campaign mantra "It's the economy, stupid!" President Clinton stated that "technology is the engine of economic growth," and he has undertaken policies to ensure the competitive advantage to U.S. industry for winning the new "economy war." Policymakers' emphasis on the utilitarian aspects of science has resulted in great apprehension within the "basic" research community, fearing that the shift undermines the wonderful symbiosis of the past 50 years between government and the science community.

Indeed it was a wonderful symbiosis—articulated in 1945 by the visionary Vannevar Bush report "Science—The Endless Frontier"—nurtured by the needs of national security and credited with contributing mightily to winning the Cold War and increasing the wealth of the nation while affording scientists the opportunity to pursue their interests in an almost unencumbered manner.

That era, however, is over. The collapse of the Soviet Union, mounting budget deficits, and demands on public funds require a new vision for science. Sustainable development, repair and maintenance of the planet, and continuous improvements in human well-being, inter alia, present an "endless frontier" of challenges for, and contributions from, the entire science community.

The natural disquietude from the search for a new rationale for funding science has been complicated by developments in the science community itself: many new Ph.D.s from U.S. universities, immigration, and restructuring of industrial R&D; the explosive growth of costs, especially in "big" science; and a few highly publicized cases of fiscal abuse or scientific misconduct.

A rather healthy dialogue is under way between the two communities, including a number of reviews, such as the Galvin Commission review for Secretary of Energy Hazel O'Leary regarding the future of the national laboratories. This thorough reexamination of the issues involved bodes well for defining the needed new vision. However, there are attitudes that are not helpful—for example, comments from some leaders of the science community that, instead of helping articulate a new vision, question the public's support of or ability to understand the issues involved and challenge the privilege of the public and its representatives to set priorities and demand accountability. There is a touch of hubris in this attitude, against which the great physicist Erwin Schrödinger warned when he wrote: "All science is bound up with human culture, in general, and . . . scientific findings, even . . . the most advanced and esoteric and difficult to grasp, are meaningless outside their cultural context. . . . A theoretical science . . . where the initiated continue musing to each other in terms that are, at best, understood by a small group of close fellow travelers, will necessarily be cut off from the rest of cultural mankind; in the long run, [this kind of science] is bound to atrophy and ossify however virulently esoteric chat may continue within its joyfully isolated groups of experts."

Although there is no basis for entitlement, continued leadership in basic science is critical. Attempts to undermine the magnificent edifice of U.S. science must be resisted, for strong basic science may not guarantee technological breakthroughs, but it certainly makes them more likely. Therefore, the debate needs to focus on setting national goals and priorities, and on how to best canalize the finite resources to achieve these national goals.

The so-called Apollonian science—goal oriented and milestone checked—has been the dominant approach even during the great symbiosis of the government and the science community, when the mantra was "national security." The approach is particularly appropriate in an era of limited resources, provided that Dionysian science—opportunities for serendipitous discovery and unprogrammed breakthroughs—is not stifled, and that the tyranny of micromanagement and the promise or requirement of unrealistic expectations can be avoided. Finally, the deconstructing of industrial R&D must also be reexamined.

Corrections

- This issue, page 46: In the top headline, total industrial R&D spending, not chemical industry R&D spending, rose 4% in 1993 to $126 billion; chemical industry R&D spending rose 10% to $18.4 billion.
- Aug. 8, page 8: American Home Products owns a majority stake in Genetics Institute, not Immunex. American Cyanamid is the majority owner of Immunex.

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Facts & Figures
FOR
CHEMICAL R&D

Mairin B. Brennan and
Janice R. Long,
C&EN Washington

Total R&D spending in the U.S. seems to be growing very slowly this year. C&EN estimates that overall support for R&D will rise only 1% in 1994. R&D performed by the chemical industry, however, like that performed at universities and colleges in the disciplines of chemistry and chemical engineering, is growing faster.

But that bottom line is only a small part of the information contained in C&EN's annual report Facts & Figures for Chemical R&D. The following 26 pages of text, tables, and graphs measure the pulse and many other vital signs of the enterprise closest to the hearts of many chemical professionals. This special report details not only where R&D funds are coming from and where they are spent but also the changing demographics of the new graduates entering the profession and how the overall U.S. R&D effort stacks up against those of some of the country's major foreign competitors.

According to estimates from the National Science Foundation, U.S. industry as a whole will spend $101 billion to support industry-conducted R&D this year—only 2% more than it did last year. NSF predicts that federal support for R&D will be $71 billion, unchanged from last year's levels. Together, these two sources have, in recent years, accounted for about 94% of total R&D spending, with the rest coming from universities, other nonprofit institutions, and industrial support for R&D conducted at universities. Although estimates of 1994 spending from these other sources are not yet available from NSF, C&EN estimates that total R&D spending this year will be about $183 billion. That's up a very modest 1% from 1993.

The federal government's curb on the growth of its share of R&D funding in 1994 follows an estimated 9% gain in 1993. This year, funding for the Department of Defense—the federal department with the largest R&D budget—is expected to drop 4% to $37.5 billion, or 53% of federal R&D funds. DOD's share of these funds has been shrinking since the late 1980s, when it was as high as 64%. DOD funding is heavily weighted toward the development side of R&D, with 88% of this

1 FEDERAL GOVERNMENT

Spending on R&D, particularly in chemistry and chemical engineering, by the federal government and by various federal agencies. Page 39

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Merck & Co. photo

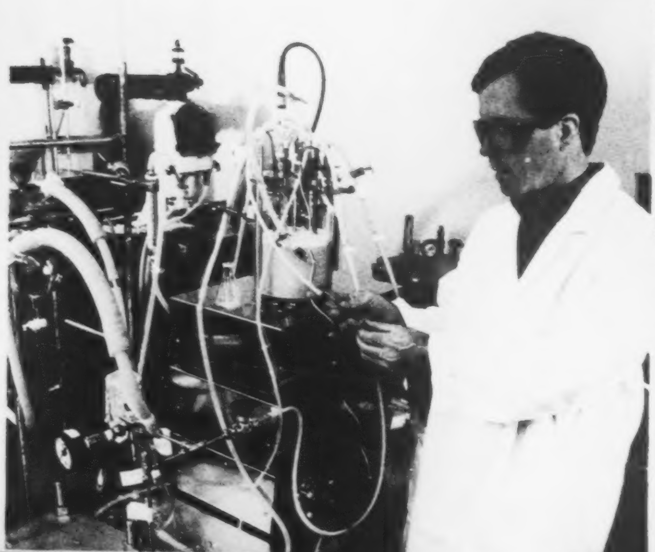


Photo by Peggy Greb, courtesy of USDA

Photo by H. Mark Weidman, courtesy of Rohm and Haas

year's R&D support to be spent on development.

Other than DOD, the biggest federal supporter of research is the Department of Health & Human Services, which does so primarily through its biomedical research arm, the National Institutes of Health. HHS's R&D budget will grow 4% to $10.7 billion in 1994, NSF estimates. Nearly 60% of that, or $6.1 billion, will support basic research.

Another major source of federal research funding—the National Science Foundation—has also come out on the plus side in this year's zero-sum game of federal R&D support. NSF estimates that its own overall R&D spending will rise 7% in 1994 to $2.22 billion, a bigger gain than the agency's 6% annual growth rate since 1987.

For a few agencies, in fact, 1994 will be a windfall year for R&D funds. As might be expected, the Clinton Administration's emphasis on environmental technologies and competitiveness is reflected in large increases in funding for R&D at the Environmental Protection Agency and the Commerce Department. EPA funds are expected to increase 26% to $656 million in 1994, following an 8% rise in 1993. Commerce is slated to receive an estimated $899 million in R&D funding, or 22% more than in 1993, when the agency's funding was boosted 13% from the year before.

Just over 40% of Commerce's R&D funds in 1994 are being allotted to the National Institute of Standards & Technology (NIST). Among other functions, NIST administers the Clinton Administration's Advanced Technology Program, which provides cost-shared grants to industry for development of high-risk technologies with significant commercial potential. NIST R&D funding will be up 46% this year to an estimated $382 million. Despite the big jump in funds, however, EPA and Commerce account for only 2% of federal R&D funds in 1994.

Federal funding for research in chemistry, which had been growing 6% annually since 1987, is expected to rise only 3% in 1994 to $1.05 billion. Funding for research in chemical engineering follows the same pattern: Compared with an annual growth rate of 8% since 1987, federal support this year will increase just 3% to $364 million. Still, with overall federal R&D monies frozen this year, any increase has to be counted as good news. By contrast, federal funds for physics research are expected to drop 4% to $2.70 billion, probably reflecting the demise of the Superconducting Super Collider.

Federal funding for university research in chemistry will also be up this year, growing 5% to an estimated $431 million, with NSF and NIH providing 69% of the funds. Although both agencies are contributing more than they did in 1993, the rise in support lags the annual growth rate since 1987. DOD, on the other hand, which has either cut or flattened its funding in just about all areas of R&D this year, is increasing funding for university research in chemistry by 16% to an estimated $62.3 million, or 14% of all federal support for such research.

Although overall industrial R&D spending will be up only modestly this year, it grew an estimated 4% both last year and in 1992, according to NSF data. Comparisons with earlier years are harder to make, however. That's because NSF's most recent industrywide survey, conducted in 1992, sampled 23,000 firms, up from 14,000 the agency surveyed previously. For the year in which the two surveys overlap, the new one shows considerably more industrial R&D spending than the old one did. Total industrial R&D spending in 1991, for example, jumped from $102 billion in the old survey to $117 billion in the new one, a difference of 15%. The agency has not revised data prior to 1991 to reflect this change.

Spending within the chemical industry will likely rise faster this year than for industry overall. Data for 1993 certainly show that R&D budgets at drug firms, in particular, were growing rapidly. On the basis of NSF data, C&EN estimates that R&D funding at companies throughout the chemicals and allied products industry increased 10% in 1993 to $18.4 billion, boosted by a 17% increase at drug firms. Drug firms last year performed 56% of the R&D of this industry group ($10.3 billion), up from 41% ($3.66 billion) in 1986.

Drug companies employed 42,600 scientists and engineers in 1993, 10% more than in 1992. By comparison, industrial chemical companies employed only 29,600, down 1% from the year before, and other chemical firms employed 17,000, the same as in 1992. Drug companies also far outstripped other chemical firms in the average number of scientists and engineers (108) per 1,000 employees in 1992. That year, on average, industrial chemical firms employed 66, and other chemical firms 53, scientists and engineers per 1,000 employees.

Universities and colleges increased their R&D effort in science and engineering by a healthy 7% to $18.9 billion in 1992, the latest year for which data are available. However, that's less than the annual 10% growth universities had been averaging for the decade.

The federal government, the largest source of academic R&D funds, hiked its funding by 8% to $11.1 billion in 1992. That's a little less than the 9% annual gains these funds have been averaging since 1982. University funding for its own R&D grew 5% to $3.58 billion, far below the 12% annual increase for the decade as a whole. Industry, too, restrained its contribution ($1.30 billion) to an increase of 8% over 1991, down from 14% annually since 1982. In 1992, federal funds accounted for 59% of academic R&D spending; university funds, 19%; and industrial support, 7%.

Universities reined in chemistry's share of R&D spending in 1992 more than any other field of science or engineering except computer science. Chemical R&D spending at universities increased only 4% to $701 million, following a 9% annual increase for the decade. (R&D spending for computer science remained at the same level as the year before, after rising 17% annually since 1982.) In tune with the overall tightening of academic R&D spending, chemical engineering's share rose 7% in 1992 (to $262 million), after a 13% annual rise for the decade.

Despite spending 3% less in 1992, the University of Texas, Austin, outranked all other schools in money spent on chemical R&D ($16 million) that year, as it had in 1991, according to data collected from the schools by NSF. Harvard University, which boosted spending 14% in 1992 to $14.1 million, moved into second place from fifth in 1991. Massachusetts Institute of Technology, which spent $14 million on chemical R&D funding in 1992, 15% less than the year before, dropped to third place, down a notch from 1991. Federal funds accounted for just over half of the University of Texas' chemical R&D support, 88% of Harvard's, and 89% of MIT's in 1992.

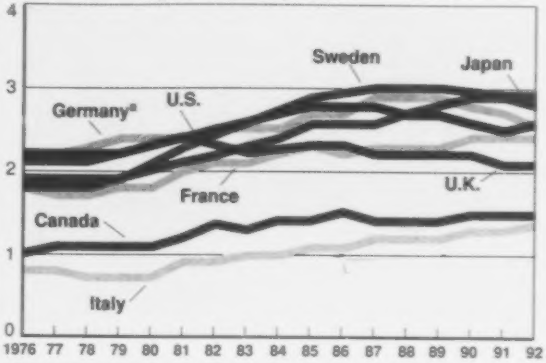
MIT led all other schools in spending on chemical engineering R&D in 1992, at $13.0 million, although it spent 23% less than in 1991, when it also ranked first. Texas A&M University moved into second place, spending $12.4 mil-

TOTAL AND NONDEFENSE R&D: U.S. reverses 1991 cut in total and nondefense spending

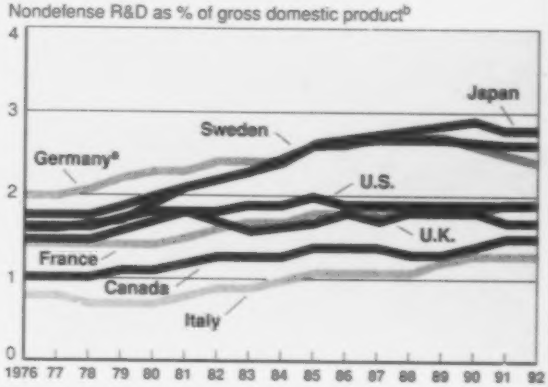
$ Billions, constant 1987	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992[a]	% annual change 1991–92	% annual change 1982–92
TOTAL R&D													
U.S.	$95.5	$102.3	$111.1	$120.6	$123.3	$125.4	$128.7	$129.7	$129.3	$123.5	$127.6	3%	3%
Japan	30.9	33.5	36.0	40.0	40.6	43.4	46.9	51.3	55.5	57.2	56.5	–1	6
Germany[b]	21.1	21.4	21.8	24.0	24.5	26.1	27.0	28.0	28.2	30.3	30.0	–1	4
France	15.0	15.5	16.4	17.0	17.2	17.9	18.7	19.8	21.0	21.3	20.8	–2	3
U.K.	na	14.4	na	15.6	16.5	16.8	17.0	17.6	17.7	16.1	16.5	2	2[c]
Italy	6.0	6.4	7.0	7.9	8.2	8.9	9.4	9.9	10.6	11.0	11.6	5	7
Canada	4.7	4.8	5.2	5.6	5.9	6.0	6.1	6.1	6.5	6.7	6.7	0	4
Sweden	na	2.8	na	3.3	na	3.6	na	3.8	na	3.5	na	na	na
NONDEFENSE R&D[d]													
U.S.	$69.2	$ 73.6	$ 79.0	$ 84.9	$ 85.2	$ 86.2	$ 90.1	$ 92.3	$ 94.0	$ 90.1	$ 94.5	5%	3%
Japan	30.7	33.3	35.7	39.7	40.3	43.1	46.5	50.9	55.0	56.7	56.0	–1	6
Germany[b]	20.2	20.4	20.8	22.7	23.3	24.9	25.7	26.7	26.7	29.0	28.7	–1	4
France	11.6	12.2	12.9	13.4	13.5	14.0	14.5	15.5	16.1	16.9	16.9	0	4
U.K.	na	10.6	na	11.5	12.6	13.2	13.9	14.5	14.7	13.1	13.3	2	3[b]
Italy	5.8	6.2	6.6	7.5	7.8	8.5	8.8	9.3	10.2	10.5	11.0	5	7
Canada	4.6	4.7	5.0	5.5	5.8	5.8	5.9	5.9	6.3	6.5	6.6	2	4
Sweden	na	2.5	na	3.0	na	3.2	na	3.4	na	3.1	na	na	na

a Preliminary. **b** Data prior to 1991 are for the former West Germany only. **c** 1983–92. **d** Estimated. **na** = not available.
Sources: National Science Foundation and Organization for Economic Cooperation & Development

Sweden leads other nations in share of gross domestic product spent on R&D . . .



. . . and Japan is frontrunner in share spent on nondefense R&D



a Data prior to 1991 are for former West Germany only. b Estimated. **Source:** National Science Foundation

lion, or 24% more than it spent in 1991, when it held third place. Federal funds accounted for 64% of MIT's support in chemical engineering R&D in 1992 but only 16% of Texas A&M's.

A few more people received doctorate degrees in chemistry in 1992 than in 1991, according to data from both the National Center for Education Statistics (NCES) and NSF. According to NCES, 2,280 doctorate degrees in chemistry were awarded in 1992, 2% more than the year before. NSF recorded 2,222 such degrees in 1992, up 1% from 1991. The slightly different numbers come about because NCES collects its data from degree-granting institutions, whereas NSF surveys graduates directly. The American Chemical Society's Committee on Professional Training reports 2,202 chemistry Ph.D. graduates in 1992 from schools that have ACS-approved undergraduate curricula. That's 11 fewer than in 1991.

According to NSF data, U.S. citizens earned 59% of U.S. doctoral degrees in 1992, down substantially from their 76% share in 1982. Of the U.S. citizens earning Ph.D.s, 90% were white and 73% were male. A decade earlier, 93% were white and 84% were male. In fact, the decade saw a 1%-per-year decrease in the number of male U.S. citizens getting Ph.D. degrees in chemistry, while the number of women in this group rose 5% per year.

Asians, Hispanics, blacks, and Native Americans collectively earned a total 116 of the Ph.D. degrees in chemistry awarded to U.S. citizens in 1992, 12 fewer than in 1991. More than half of these degrees (63) went to Asians, 34 to Hispanics, 13 to blacks, and six to Native Americans. (An additional 20 degrees went to recipients who did not identify themselves according to ethnic group.)

The number of postdoctoral fellows in science and engineering grew 5% annually, from 14,672 in 1982 to 24,024 in 1992. However, unlike in all other disciplines, postdoctoral appointments in both chemistry and chemical engineering declined in 1992. Appointments in chemistry were off 2%, compared with a 2% annual growth for the decade as a whole; in chemical engineering, they fell 4%, compared with a hefty 12% annual rise since 1982.

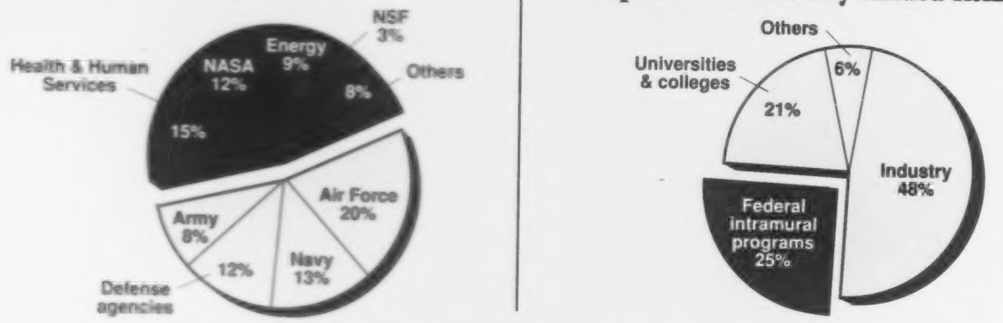
In absolute expenditures in R&D, of course, the U.S. far outspends any other country. In 1992, for example, the U.S. spent more than twice as much as Japan and more than four times as much as Germany. And for that one year at least, the gap widened. After adjustment for inflation, U.S. R&D spending increased 3% in 1992 to $128 billion (constant 1987 dollars), matching its annual growth rate for the decade. In contrast, Japan cut its spending 1% to $56.5 billion, although for the decade as a whole, this spending rose at an annual rate of 6%. Germany's spending, which grew 4% annually for the decade as a whole, fell 1% in 1992 to $30.0 billion.

The U.S. boosted nondefense R&D spending 5% in 1992 to $94.5 billion. It had been growing at an annual rate of 3% since 1982. Both Japan and Germany, which allot virtually all of their R&D spending to nondefense work, dropped nondefense spending 1% to $56.0 billion and $28.7 billion, respectively.

Since 1989, the U.S. hasn't compared well with Japan in R&D spending as a percentage of gross domestic product. Share of GDP—the value of all goods and services produced in a country—is often used to compare the R&D efforts of different countries, because it takes into account differences in the economic base of each country. The fraction of GDP spent on R&D for the U.S. dropped from 2.7% in 1989 to 2.5% in 1991 and then rose in 1992 to 2.6%. During the same period, Japan's R&D spending ranged between 2.8 and 2.9% of GDP. The fraction of GDP spent on nondefense R&D in the U.S. held steady at 1.9%.

In 1993, the U.S. issued 30,743 chemical patents, of which 49% were issued to U.S. corporations, 9% to individuals in the U.S. and abroad, and 42% to corporations with foreign addresses. Japanese companies and individuals continued to claim the greatest share of U.S. chemical patents going abroad, claiming 22% of the total in 1993. In 1983, Japan received 15%. Both Italy and Belgium had sizable increases last year in the number of U.S. chemical patents they were awarded—Italy's take moved up 15% to 494 and Belgium's moved up 16% to 204. South Korea and Taiwan widened the dent they made in 1992 in the U.S. chemical patents market: South Korea was awarded 164 patents in 1993, up 61% from 1992; Taiwan received 147 patents, up 58%.

Federal R&D Funding Flat This Year, Defense Loses Ground



Nondefense agencies fund 47% of federal R&D efforts . . .

. . . and government labs perform one quarter of federally funded R&D

Estimated fiscal 1994 federal obligations for R&D = $71.2 billion

Source: National Science Foundation

FEDERAL OBLIGATIONS FOR R&D: Commerce, EPA post strong gains, NSF rises also

$ Millions	1987	1988	1989	1990	1991	1992	1993[a]	1994[a]	% annual change 1993–94	% annual change 1987–94
Defense	$35,232	$35,249	$37,577	$37,268	$32,135	$36,130	$38,987	$37,523	–4%	1%
Air Force	15,348	14,867	15,237	14,831	10,938	13,427	13,889	13,994	1	–1
Navy	9,508	9,514	9,666	9,586	7,806	8,031	10,206	9,370	–8	0
Defense agencies	5,220	5,833	6,859	6,945	7,073	7,512	8,235	8,267	0	7
Army	5,020	4,806	5,659	5,684	6,082	6,854	6,404	5,608	–12	2
Health & Human Services	6,606	7,158	7,903	8,406	9,756	8,988	10,344	10,723	4	7
NIH[b]	6,327	6,846	7,474	7,980	9,157	8,409	9,771	10,075	3	7
NASA	3,767	4,330	5,394	6,533	7,280	7,658	8,190	8,637	5	12
Energy	4,757	5,036	5,193	5,631	5,983	6,172	6,586	6,582	0	5
NSF	1,471	1,533	1,670	1,690	1,785	1,868	2,073	2,217	7	6
Agriculture	948	1,017	1,038	1,108	1,237	1,327	1,331	1,368	3	5
Agricultural Research Service	479	506	524	546	591	627	626	640	2	4
Cooperative State Research Service	271	298	307	324	377	418	419	417	0	6
Forest Service	127	136	131	159	175	181	187	215	15	8
Commerce	402	389	398	438	490	651	736	899	22	12
National Oceanic & Atmospheric Administration	286	263	269	300	338	462	466	504	8	8
National Institute of Standards & Technology	99	108	116	122	140	179	261	382	46	21
Transportation	325	305	303	367	380	445	747	688	–8	11
EPA	348	347	380	420	433	484	521	656	26	9
Interior	404	417	468	509	593	609	612	589	–4	6
Geological Survey	227	236	260	308	357	361	355	362	2	7
Others	974	974	1,081	1,191	1,223	1,262	1,319	1,362	3	5
TOTAL	$55,254	$56,770	$61,406	$63,561	$61,295	$65,594	$71,446	$71,244	0%	4%
ANNUAL CHANGE	7%	3%	8%	4%	–4%	7%	9%	0%		

Note: Fiscal years. Does not include funds for R&D plant. **a** Estimated. **b** Includes funds previously reported for the Alcohol, Drug Abuse & Mental Health Administration, which became part of NIH in fiscal 1993. **Source:** "Survey of Federal Funds for Research and Development," National Science Foundation

PERFORMERS OF FEDERALLY FUNDED R&D: Federal intramural programs grow modestly

Federal obligations, $ millions	1987	1988	1989	1990	1991	1992	1993[a]	1994[a]	% annual change	
									1993–94	1987–94
Industry	$28,628	$28,630	$30,508	$31,568	$28,489	$31,755	$34,705	$34,190	–1%	3%
FFRDCs[b] administered by industry	1,860	1,911	1,960	2,198	2,068	2,010	1,310	1,253	–4	–5
Federal intramural programs	13,413	14,115	15,121	15,978	15,238	15,690	17,199	17,542	2	4
Universities and colleges	10,548	11,302	12,169	12,588	13,773	14,127	14,831	14,909	1	5
FFRDCs[b] administered by universities	3,210	3,474	3,497	3,450	3,604	3,856	3,495	3,269	–6	0
Nonprofit institutions	2,222	2,189	2,522	2,870	3,316	3,550	4,183	4,078	–3	9
FFRDCs[b] administered by nonprofit institutions	511	506	522	622	679	746	823	902	10	8
Foreign	295	392	919	343	264	288	274	268	–2	–1
State and local governments	148	142	167	214	215	184	254	257	1	8
TOTAL	$55,254	$56,770	$61,406	$63,561	$61,295	$65,594	$71,446	$71,244	0%	4%
ANNUAL CHANGE	7%	3%	8%	4%	–4%	7%	9%	0%		

Note: Fiscal years. **a** Estimated. **b** Federally funded R&D centers. **Source:** "Survey of Federal Funds for Research and Development," National Science Foundation

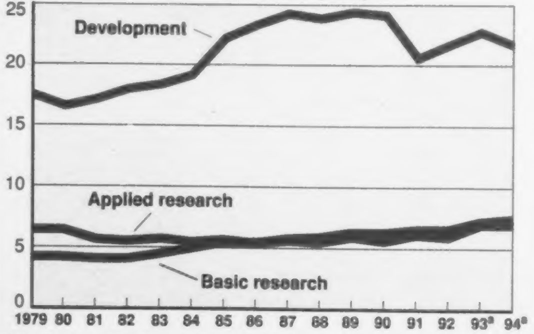
FEDERAL OBLIGATIONS FOR SCIENTIFIC DISCIPLINES: Chemistry gains 3% in fiscal 1994

$ Millions for research only	1987	1988	1989	1990	1991	1992	1993[a]	1994[a]	% annual change	
									1993–94	1987–94
Life sciences	$ 7,341	$ 7,725	$ 8,495	$ 8,830	$ 9,622	$ 9,911	$10,950	$11,373	4%	6%
Engineering	3,906	3,956	4,442	4,227	4,945	4,977	5,840	6,006	3	6
Metallurgy and materials	362	457	521	555	711	727	714	842	18	13
Chemical	216	258	142	242	304	298	354	364	3	8
Physical sciences	3,253	3,317	3,705	3,809	4,235	4,439	4,916	4,833	–2	6
Physics	1,854	1,975	2,191	2,255	2,461	2,578	2,805	2,703	–4	6
Chemistry	680	703	783	762	828	896	1,023	1,052	3	6
Environmental sciences	1,512	1,607	1,773	2,174	2,150	2,208	2,412	2,542	5	8
Mathematical and computer sciences	641	643	735	841	904	1,160	1,363	1,469	8	13
Other sciences	1,288	1,402	1,616	1,741	2,112	1,796	1,971	1,901	–4	6
TOTAL	$17,941	$18,650	$20,766	$21,622	$23,968	$24,491	$27,452	$28,124	2%	7%
ANNUAL CHANGE	9%	4%	11%	5%	10%	8%	6%			

Note: Fiscal years. **a** Estimated. **Source:** "Survey of Federal Funds for Research and Development," National Science Foundation

In constant dollars, support for development is losing ground this year

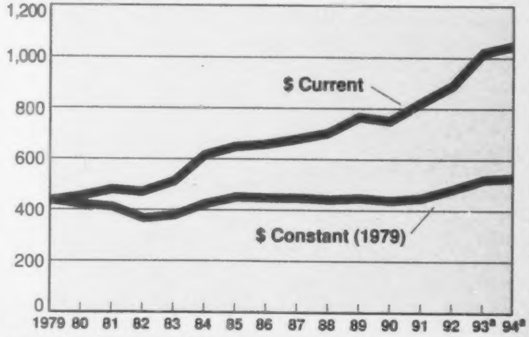
Federal obligations, $ billions, constant (1979)



Note: Fiscal years. Constant-dollar values calculated by C&EN from NSF data. **a Estimated. Source:** National Science Foundation

After three-year climb, real support for chemical research is leveling off

Federal obligations, $ millions



Note: Fiscal years. Constant-dollar values calculated by C&EN from NSF data. **a Estimated. Source:** National Science Foundation

FEDERAL OBLIGATIONS FOR BASIC RESEARCH: No gains for Energy or Defense, but NSF up 7%

$ Millions	1987	1988	1989	1990	1991	1992	1993[a]	1994[a]	% annual change	
									1993–94	1987–94
Health & Human Services	$3,828	$4,081	$ 4,388	$ 4,649	$ 5,050	$ 5,059	$ 5,884	$ 6,067	3%	7%
NIH[b]	3,808	4,061	4,361	4,648	5,049	5,057	5,882	6,065	3	7
NSF	1,371	1,433	1,563	1,586	1,676	1,741	1,921	2,048	7	6
NASA	1,014	1,113	1,417	1,637	1,706	1,738	1,952	1,991	2	10
Energy	1,069	1,185	1,411	1,505	1,686	1,736	1,775	1,782	0	8
Defense	908	877	948	948	994	1,099	1,238	1,237	0	5
Navy	354	342	354	365	388	394	406	433	7	3
Defense agencies	115	173	204	201	208	294	381	347	–9	17
Air Force	222	196	203	197	209	206	239	246	3	1
Army	217	166	187	185	189	205	213	210	–1	0
Agriculture	446	481	485	519	558	595	597	631	6	5
Agricultural Research Service	253	271	283	294	310	326	326	335	3	4
Cooperative State Research Service	133	146	143	154	170	190	190	205	8	6
Forest Service	49	52	50	60	67	69	71	82	15	8
Interior	135	127	189	205	229	231	229	213	–7	7
Geological Survey	85	90	140	159	179	180	177	176	–1	11
Bureau of Mines	46	32	44	41	43	44	46	29	–37	–6
EPA	31	27	51	74	91	110	114	180	58	29
Smithsonian Institution	72	75	80	84	98	98	100	101	1	5
Commerce	26	31	29	31	34	35	37	40	8	6
National Institute of Standards & Technology	25	26	28	29	32	34	37	40	8	7
Others	42	44	41	48	49	48	50	56	12	4
TOTAL	$8,942	$9,474	$10,602	$11,286	$12,171	$12,490	$13,897	$14,346	3%	7%
ANNUAL CHANGE	10%	6%	12%	6%	8%	3%	11%	3%		

Note: Fiscal years. **a** Estimated. **b** Includes funds previously reported for the Alcohol, Drug Abuse & Mental Health Administration, which became part of NIH in fiscal 1993.
Source: "Survey of Federal Funds for Research and Development," National Science Foundation

FEDERAL OBLIGATIONS FOR APPLIED RESEARCH: NASA gets big increase, but Defense loses

$ Millions	1987	1988	1989	1990	1991	1992	1993[a]	1994[a]	% annual change	
									1993–94	1987–94
Health & Human Services	$2,194	$2,416	$ 2,700	$ 2,818	$ 3,112	$ 2,887	$ 3,257	$ 3,418	5%	7%
NIH[b]	1,980	2,173	2,393	2,489	2,568	2,341	2,716	2,801	3	5
Defense	2,440	2,362	2,708	2,582	2,724	2,975	3,637	3,179	–13	4
Defense agencies	751	792	1,038	965	945	1,163	1,409	1,245	–12	7
Air Force	563	577	605	579	621	585	740	766	4	4
Army	693	588	636	595	672	728	857	631	–26	–1
Navy	433	406	429	443	486	499	632	536	–15	3
NASA	1,256	1,219	1,461	1,424	1,667	1,491	1,606	2,105	31	8
Energy	1,029	1,051	1,021	1,066	1,587	1,676	1,827	1,731	–5	8
Commerce	313	312	322	346	415	561	596	703	18	12
National Oceanic & Atmospheric Administration	234	225	235	252	316	439	426	469	10	10
National Institute of Standards & Technology	64	73	78	83	93	116	163	225	38	20
Agriculture	473	505	517	542	618	666	667	669	0	5
Agricultural Research Service	201	208	209	218	241	257	257	261	2	4
Cooperative State Research Service	138	153	165	171	206	229	229	212	–7	6
Forest Service	74	80	78	94	104	107	110	127	15	8
Transportation	69	91	121	119	115	156	330	279	–15	22
EPA	246	241	223	242	262	294	327	397	21	7
Interior	247	266	253	270	324	340	344	332	–3	4
Geological Survey	132	136	127	134	159	164	165	174	5	4
NSF	99	100	108	103	109	127	151	170	13	8
Others	632	614	730	825	865	827	813	795	–2	3
TOTAL	$8,998	$9,177	$10,164	$10,337	$11,798	$12,000	$13,555	$13,778	2%	6%
ANNUAL CHANGE	8%	2%	11%	2%	14%	2%	13%	2%		

Note: Fiscal years. **a** Estimated. **b** Includes funds previously reported for the Alcohol, Drug Abuse & Mental Health Administration, which became part of NIH in fiscal 1993.
Source: "Survey of Federal Funds for Research and Development," National Science Foundation

FEDERAL OBLIGATIONS FOR DEVELOPMENT: Commerce's budget up 50%, led by gains for NIST

$ Millions	1987	1988	1989	1990	1991	1992	1993[a]	1994[a]	% annual change 1993–94	% annual change 1987–94
Defense	$31,884	$32,010	$33,921	$33,739	$28,417	$32,056	$34,111	$33,107	–3%	1%
Air Force	14,563	14,094	14,430	14,055	10,107	12,637	12,911	12,982	1	–2
Navy	8,721	8,766	8,883	8,779	6,932	7,138	9,168	8,401	–8	–1
Defense agencies	4,354	4,868	5,617	5,780	5,919	6,114	6,445	6,674	4	6
Army	4,110	4,052	4,836	4,904	5,221	5,922	5,334	4,767	–11	2
NASA	1,518	1,999	2,515	3,473	3,909	4,428	4,632	4,541	–2	17
Energy	2,659	2,801	2,761	3,060	2,710	2,760	2,984	3,069	3	2
Health & Human Services	584	661	814	939	1,594	1,042	1,203	1,238	3	11
NIH[b]	538	613	720	842	1,450	1,011	1,173	1,209	3	12
Transportation	256	213	183	247	265	288	414	407	–2	–7
Commerce	64	47	47	61	40	55	103	154	50	13
National Institute of Standards & Technology (NIST)	9	9	10	11	16	30	61	116	90	44
National Oceanic & Atmospheric Administration	52	35	34	48	22	24	40	35	–13	–5
EPA	71	80	107	105	80	80	80	79	–1	2
Agriculture	29	31	36	47	61	66	67	68	1	13
Agricultural Research Service	24	26	31	33	40	44	44	44	0	9
Interior	22	24	27	33	40	39	39	44	13	10
Geological Survey	10	11	13	15	18	17	13	12	–8	3
Others	226	253	230	233	211	288	360	413	15	9
TOTAL	$37,313	$38,119	$40,641	$41,937	$37,327	$41,102	$43,993	$43,120	–2%	2%
ANNUAL CHANGE	7%	2%	7%	3%	–11%	10%	7%	–2%		

Note: Fiscal years. a Estimated. b Includes funds previously reported for the Alcohol, Drug Abuse & Mental Health Administration, which became part of NIH in fiscal 1993.
Source: "Survey of Federal Funds for Research and Development," National Science Foundation

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ENGINEERING RESEARCH: Energy contributes 40% of funding for chemical engineering in

Federal obligations, $ millions	1989			1990			1991		
	All engineering	Chemical engineering	Metallurgy & materials	All engineering	Chemical engineering	Metallurgy & materials	All engineering	Chemical engineering	Metallurgy & materials
Defense	$1,836.2	$ 46.9	$343.4	$1,762.2	$ 37.4	$370.5	$1,938.0	$ 41.9	$493.1
Defense agencies	480.5	0.2	221.6	466.7	1.8	42.6	606.2	0	320.2
Air Force	565.1	11.6	42.9	509.8	0	240.8	498.2	3.3	39.7
Navy	389.9	11.6	56.1	408.8	11.5	59.7	403.4	9.6	88.8
Army	400.6	23.4	22.7	377.0	24.0	27.3	430.3	29.0	44.5
NASA	1,446.4	6.0	35.5	1,324.6	14.3	59.8	1,478.0	12.9	74.3
Energy	406.1	4.5	78.0	435.6	105.9	78.5	723.6	142.3	72.9
NSF	232.0	42.5	28.1	171.6	35.9	7.8	262.7	49.2	28.9
Transportation	87.6	6.9	0.2	91.9	7.0	0.2	78.9	6.1	0.6
Commerce	52.7	3.2	11.6	56.8	3.9	11.8	65.6	4.5	14.9
EPA	52.7	19.2	0.8	61.5	24.5	0.7	60.9	31.4	0.2
Interior	92.8	5.8	23.4	88.4	5.8	25.1	97.5	7.1	25.1
Agriculture	34.5	7.2	0	38.9	7.3	0	435.0	7.9	0
TOTAL	$4,241.0	$142.2	$521.0	$4,031.5	$242.0	$554.4	$5,140.2	$303.3	$710.0
ANNUAL CHANGE	13%	–45%	14%	–5%	70%	6%	28%	25%	28%

Note: Fiscal years. These nine agencies provide 95% of all engineering funds and 100% of funds for chemical and metallurgy and materials engineering. a Estimated.
Source: "Survey of Federal Funds for Research and Development," National Science Foundation

FEDERAL OBLIGATIONS FOR CHEMICAL RESEARCH: Three agencies provide 55% of support

$ Millions	1987	1988	1989	1990	1991	1992	1993[a]	1994[a]	% annual change	
									1993–94	1987–94
Energy	$145.5	$162.9	$213.4	$189.2	$187.6	$219.3	$ 233.2	$ 221.0	–5%	6%
NSF	115.3	120.6	127.4	133.2	151.7	135.4	180.5	190.3	5	7
NIH[b,c]	115.5	123.8	107.9	112.2	119.9	136.7	160.1	164.9	3	5
Defense	144.9	125.0	133.5	121.0	138.5	136.6	158.3	151.8	–4	1
Air Force	43.3	43.6	43.2	41.2	43.2	46.7	57.9	46.0	–21	1
Army	72.2	57.5	60.4	50.4	54.0	39.1	44.1	45.6	3	–6
Navy	28.4	22.1	25.5	26.5	38.4	37.4	41.2	40.5	–2	5
Defense agencies	1.1	1.8	4.4	2.8	3.0	13.4	15.1	19.7	30	51
EPA	34.6	30.6	32.5	37.1	49.6	74.7	82.3	102.1	24	17
Agriculture	65.0	60.8	61.0	67.8	76.0	82.8	84.0	83.9	0	4
Agricultural Research Service	46.4	40.9	41.3	43.1	47.5	51.3	52.3	53.5	2	2
Cooperative State Research Service	11.5	12.2	12.3	15.6	18.5	24.7	24.6	22.2	–10	10
Forest Service	7.1	7.6	7.5	9.0	10.0	6.9	7.1	8.1	14	2
NASA	13.4	27.5	47.4	35.9	39.2	47.5	57.1	60.6	6	24
Commerce	22.9	23.6	24.4	25.0	27.1	29.6	33.4	40.1	20	8
National Institute of Standards & Technology	16.5	16.9	17.7	18.4	19.3	20.8	24.9	31.0	24	9
National Oceanic & Atmospheric Administration	6.4	6.7	6.7	6.7	7.8	8.8	8.6	9.1	6	5
Interior	20.9	21.9	22.0	22.9	28.2	24.9	26.2	29.0	11	5
Geological Survey	20.2	20.8	21.9	22.9	28.2	24.9	25.2	27.5	9	5
Others	2.3	6.4	13.1	17.4	10.6	9.0	7.7	8.4	9	20
TOTAL	$680.3	$703.1	$782.6	$761.7	$828.4	$896.5	$1,022.8	$1,052.1	3%	6%
ANNUAL CHANGE	3%	3%	11%	–3%	9%	8%	14%	3%		

Note: Fiscal years. **a** Estimated. **b** Part of Department of Health & Human Services; all HHS support for chemical research comes from NIH. **c** Includes funds previously reported for the Alcohol, Drug Abuse & Mental Health Administration, which became part of NIH in fiscal 1993. **Source:** "Survey of Federal Funds for Research and Development," National Science Foundation

fiscal 1994, NSF and EPA give an additional 36%

1992			1993[a]			1994[a]		
All engineering	Chemical engineering	Metallurgy & materials	All engineering	Chemical engineering	Metallurgy & materials	All engineering	Chemical engineering	Metallurgy & materials
$2,032.7	$ 34.7	$521.6	$2,459.7	$ 43.2	$465.0	$2,251.0	$ 35.2	$522.0
751.0	5.3	311.6	871.6	5.6	288.3	777.6	7.8	284.6
440.2	3.1	91.3	537.1	4.1	37.3	579.0	4.4	114.1
409.1	7.9	84.9	491.2	10.1	99.7	441.2	8.8	92.4
432.3	18.3	33.8	559.8	23.5	39.7	453.2	14.2	30.9
1,367.8	13.3	67.4	1,517.7	18.1	79.4	1,884.8	14.6	143.6
711.3	135.1	67.1	764.6	152.9	74.6	722.1	143.5	70.5
217.1	45.5	21.9	283.3	56.0	30.4	307.4	61.0	32.0
92.6	0.4	0.9	207.9	10.5	10.4	181.0	10.4	11.8
84.4	4.8	20.1	108.7	6.4	26.7	141.5	8.2	36.3
79.1	44.8	0.4	80.8	47.6	0.3	121.5	69.4	0.3
112.5	9.0	27.8	115.4	9.6	27.0	91.2	10.4	25.8
65.3	7.1	0	66.5	7.4	0	66.3	7.9	0
$4,762.8	$294.7	$727.2	$5,604.6	$351.7	$713.8	$5,766.8	$360.6	$842.3
–7%	–3%	2%	18%	2%	–2%	3%	3%	18%

UNIVERSITY RESEARCH: Funding for chemistry accounts for a third of physical sciences budget

Federal obligations, $ millions	1987	1988	1989	1990	1991	1992	1993[a]	1994[a]	% annual change 1993–94	% annual change 1987–94
Life sciences	$3,824	$4,029	$4,396	$4,532	$4,967	$5,011	$5,581	$5,715	2%	6%
Physical sciences	823	857	930	1,002	1,071	1,151	1,277	1,298	2	7
Physics	404	425	486	546	591	574	672	672	0	8
Chemistry	281	295	298	317	340	352	411	431	5	6
Engineering	600	673	749	713	829	836	934	984	5	7
Metallurgy and materials	108	175	194	166	214	183	186	192	3	9
Chemical	55	57	42	59	76	70	81	83	2	6
Environmental sciences	400	408	460	489	489	585	665	688	3	8
Mathematical and computer sciences	289	305	345	415	399	478	542	596	10	11
Other sciences	449	494	593	636	709	586	684	693	1	6
TOTAL	$6,385	$6,766	$7,473	$7,787	$8,464	$8,647	$9,683	$9,974	3%	7%
ANNUAL CHANGE	14%	6%	10%	15%	9%	2%	12%	3%		

Note: Fiscal years. Includes funding only from six agencies that together represent about 96% of federal research support to universities in fiscal 1994. **a** Estimated.
Source: "Survey of Federal Funds for Research and Development," National Science Foundation

UNIVERSITY RESEARCH IN CHEMISTRY: NSF provides 43% of total support

Federal obligations, $ millions	1987	1988	1989	1990	1991	1992	1993[a]	1994[a]	% annual change 1993–94	% annual change 1987–94
NSF	$107.1	$111.6	$118.5	$130.6	$150.3	$133.9	$176.1	$186.2	6%	8%
NIH[b,c]	85.0	91.4	76.4	79.9	83.7	94.0	107.6	109.3	2	4
Defense	45.0	41.3	42.0	41.9	41.5	50.9	53.5	62.3	16	5
Defense agencies	17.2	13.6	14.3	16.2	15.8	13.4	14.3	19.1	34	50
Air Force	18.4	17.0	15.5	17.1	15.8	14.6	15.2	19.0	25	0
Navy	1.1	1.8	4.4	2.8	3.0	16.0	17.1	18.0	5	1
Army	8.3	8.8	7.7	5.8	6.8	6.9	6.9	6.2	–10	–4
Energy	28.5	33.8	43.7	44.7	39.9	44.3	44.2	45.6	3	7
Agriculture	11.2	11.8	11.8	14.4	18.6	23.4	23.4	20.9	–11	9
NASA	4.3	4.8	5.2	6.0	5.7	5.2	6.5	6.7	3	7
TOTAL	$281.1	$294.7	$297.7	$317.5	$339.7	$351.7	$411.3	$431.0	5%	6%
ANNUAL CHANGE	6%	5%	1%	7%	7%	4%	17%	5%		

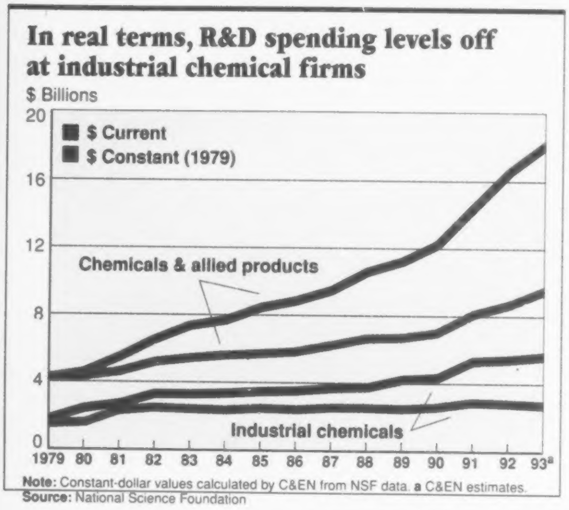
Note: Fiscal years. Funding from these six agencies represent about 96% of federal obligations in fiscal 1994. **a** Estimated. **b** Part of Department of Health & Human Services; all HHS support for chemical research comes from NIH. **c** Includes funds previously reported for the Alcohol, Drug Abuse & Mental Health Administration, which became part of NIH in fiscal 1993.
Source: "Survey of Federal Funds for Research and Development," National Science Foundation

FEDERAL OBLIGATIONS FOR R&D PLANT: NSF gains 34% amidst a general plunge

$ Millions	1987	1988	1989	1990	1991	1992	1993[a]	1994[a]	% annual change 1993–94	% annual change 1987–94
Energy	$ 772.2	$ 915.0	$ 873.0	$ 916.0	$1,220.1	$1,320.8	$1,424.3	$1,471.5	3%	10%
NASA	309.4	428.2	519.5	527.0	723.6	817.8	990.8	871.6	–12	16
Defense	477.2	435.8	499.3	487.3	425.7	396.5	518.6	260.5	–50	–8
Air Force	270.3	143.7	250.2	322.2	152.3	179.7	249.5	106.3	–57	–12
Navy	69.0	74.9	89.6	60.4	54.0	96.0	35.0	70.0	100	0
Defense agencies	72.1	124.4	114.4	51.6	128.4	98.8	214.1	48.2	–77	–6
Army	65.8	92.8	45.1	53.1	91.0	22.0	20.0	36.0	80	–8
NSF	61.3	56.9	53.6	39.3	159.6	101.6	137.9	185.4	34	17
Health & Human Services	36.7	19.5	78.6	107.8	86.3	96.7	375.6	159.2	–58	23
NIH[b]	35.9	19.0	55.6	84.8	67.8	82.1	340.8	128.9	–62	20
Agriculture	111.8	135.2	89.2	102.2	144.6	164.7	197.4	94.6	–52	–2
Commerce	5.2	11.2	9.1	15.4	15.7	21.0	131.2	79.2	–40	48
National Institute of Standards & Technology	2.0	10.7	8.6	8.8	8.5	11.2	116.9	68.7	–41	65
Others	72.2	55.3	42.8	76.7	77.2	65.5	82.6	70.3	–15	0
TOTAL	$1,846.0	$2,057.1	$2,165.1	$2,271.7	$2,852.8	$2,984.6	$3,858.4	$3,192.3	–17%	8%
ANNUAL CHANGE	20%	11%	5%	5%	26%	5%	29%	–17%		

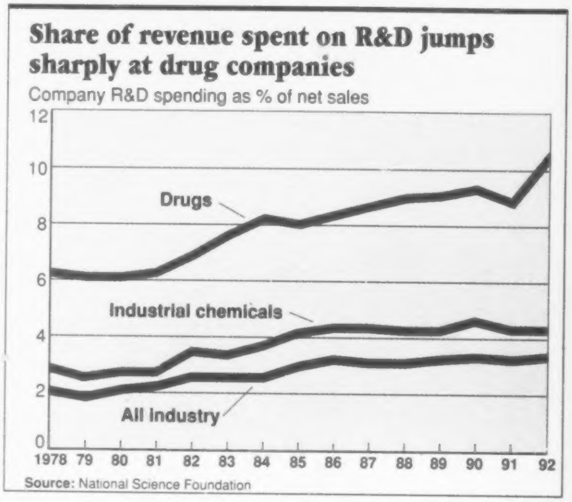
Note: Fiscal years. **a** Estimated. **b** Includes funds previously reported for the Alcohol, Drug Abuse & Mental Health Administration, which became part of NIH in fiscal 1993.
Source: "Survey of Federal Funds for Research and Development," National Science Foundation

Chemical Industry R&D Spending Rises 4% To $126 Billion



In real terms, R&D spending levels off at industrial chemical firms

Note: Constant-dollar values calculated by C&EN from NSF data. **a** C&EN estimates. **Source:** National Science Foundation



Share of revenue spent on R&D jumps sharply at drug companies

Source: National Science Foundation

TOTAL FUNDS FOR INDUSTRIAL R&D: Chemical firms perform 14% of total R&D

$ Millions	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	% annual change	
												1992–93	1983–93
Chemicals and allied products	**$ 7,185**	**$ 7,927**	**$ 8,540**	**$ 8,843**	**$ 9,635**	**$10,772**	**$ 11,466**	**$ 12,344**	**$ 14,648**	**$ 16,711**	**$ 18,350ª**	**10%**	**10%**
Industrial chemicals	3,214	3,240	3,498	3,552	3,716	3,959	4,039	4,337	5,390	5,406	5,450ª	1	5
Drugs	2,901ª	3,316ª	3,490ª	3,658	4,100ª	4,746	5,427ª	6,025ª	6,950ª	8,831	10,300ª	17	14
Other chemicals	1,070ª	1,371ª	1,552ª	1,633	1,819ª	2,067	2,100ª	2,182ª	2,306ª	2,474	2,600ª	5	9
Other industries	**58,083**	**66,873**	**75,699**	**78,980**	**82,520**	**87,117**	**90,388**	**92,000**	**102,304**	**104,603**	**107,550ª**	**3**	**6**
TOTAL	**$65,268**	**$74,800**	**$84,239**	**$87,823**	**$92,155**	**$97,889**	**$101,854**	**$104,344**	**$116,952**	**$121,314**	**$125,900ᵇ**	**4%**	**7%**

Note: Monies are for R&D performed in the U.S. **a** C&EN estimates. **b** Preliminary data. **Source:** "Research and Development in Industry," National Science Foundation

COMPANY FUNDS FOR INDUSTRIAL R&D: Outlays for drug R&D jumps 25% in 1992

$ Millions	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	% annual change	
												1991–92	1982–92
Chemicals and allied products	**$ 6,197**	**$ 6,792**	**$ 7,736**	**$ 8,310**	**$ 8,664**	**$ 9,445**	**$10,573**	**$11,383**	**$12,277**	**$14,439**	**$16,420**	**14%**	**10%**
Industrial chemicals	2,810	2,828	3,057	3,281	3,374	3,531	3,763	3,960	4,272	5,225	5,152	1	6
Drugs	2,473	2,896	3,310	3,481	3,657	4,095	4,743	5,164	5,366	6,947	8,822	25	14
Other chemicals	914	1,068	1,369	1,548	1,633	1,819	2,067	2,259	2,638	2,267	2,447	8	10
Other industries	**33,908**	**37,796**	**43,668**	**48,733**	**51,268**	**51,958**	**55,199**	**59,179**	**61,703**	**76,141**	**80,234**	**5**	**9**
TOTALª	**$40,105**	**$44,588**	**$51,404**	**$57,043**	**$59,932**	**$61,403**	**$65,772**	**$70,562**	**$73,980**	**$90,580**	**$96,654**	**7%**	**9%**

Note: Monies are for R&D performed in the U.S. and include funds from nonfederal sources such as research institutions, nonprofit organizations, and the like. **a** Totals may not add because of rounding. **Source:** "Research and Development in Industry," National Science Foundation

FEDERAL FUNDS FOR INDUSTRIAL R&D: Chemical industry's share is growing rapidly

$ Millions	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	% annual change 1991–92	% annual change 1982–92
Chemicals and allied products	$407	$393	$191[a]	$230	$179	$192	$199	$83	$67	$209	$291	39%	–6%
Industrial chemicals	396	386	183[a]	217	178	187	196	79	65	165	254	54	–4
Drugs and other chemicals	11	7	8	13	1	5	3	4	2	44[b]	36[b]	8	9
Other industries	18,138	20,287	23,205	26,966	27,712	31,119	31,918	31,209	30,559	26,163	24,369	–7	3
TOTAL	$18,545	$20,680	$23,396	$27,196	$27,891	$31,311	$32,117	$31,292	$30,626	$26,372	$24,660	–6%	3%

Note: Monies are for R&D performed in the U.S. **a** The decline in 1984 from 1983 results from the administration of federally funded Oak Ridge National Laboratory being changed from a chemical company to a company in the aircraft and missile industry. **b** C&EN estimates. **Source:** "Research and Development in Industry," National Science Foundation

R&D BY U.S. COMPANIES ABROAD: Funds spent by drug firms increase 18% in 1992

$ Millions	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	% annual change 1991–92	% annual change 1982–92
Chemicals and allied products	$ 682	$ 729	$ 786	$ 843	$1,071	$1,243	$1,501	$1,504	$1,990	$2,401	$2,683	12%	15%
Industrial and other chemicals	319	368	385	444	579	625	781	508	547	1,009	1,042	3	13
Drugs	363	361	401	399	492	618	720	996	1,443	1,392	1,641	18	16
Other industries	2,412	2,540	2,847	2,807	3,553	3,983	4,794	5,310	5,737	6,746	7,298	8	12
TOTAL	$3,094	$3,269	$3,633	$3,650	$4,624	$5,226	$6,295	$6,814	$7,727	$9,147	$9,981	9%	12%

Source: "Research and Development in Industry," National Science Foundation

R&D SPENDING: Drug firms register 8% rise, chemical firms post 3% decline in 1993

$ Millions	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1993 R&D spending as % of sales
CHEMICAL COMPANIES												
Dow Chemical	$ 492	$ 507	$ 547	$ 605	$ 670	$ 772	$ 873	$1,136	$1,159	$1,289	$1,256	7.0%
DuPont	966	1,097	1,144	1,156	1,223	1,319	1,387	1,428	1,298	1,277	1,132	3.1
Monsanto	290	370	470	596	615	648	598	612	627	651	626	7.9
Rohm and Haas	100	109	124	133	142	156	175	178	183	199	205	6.3
Lubrizol	37	33	44	51	62	65	70	74	80	90	172	11.3
Union Carbide	245	265	275	148	159	159	181	191	190	155	139	3.0
W. R. Grace	73	81	92	94	107	119	125	148	150	151	135	3.1
Air Products[a]	40	44	51	61	57	72	71	72	80	85	92	2.8
Ethyl[b]	39	40	47	47	50	59	61	65	69	73	76	3.9
Hercules	74	72	76	71	74	74	79	92	86	70	76	2.7
International Flavors	32	32	34	39	45	50	52	57	62	71	75	6.3
Morton International[c]	23	30	25	29	31	35	38	48	59	61	69	3.0
Praxair[d]	—	—	—	—	—	—	—	—	—	62	58	2.4
Nalco	30	32	32	33	35	37	41	45	47	48	50	3.6
Olin	49	52	53	56	62	58	66	66	41	39	41	1.7
Petrolite[e]	13	12	12	12	12	12	12	12	11	12	14	3.9
TOTAL	$2,503	$2,776	$3,026	$3,122	$3,344	$3,635	$3,829	$4,224	$4,142	$4,333	$4,216	4.4%
ANNUAL CHANGE	8%	11%	9%	3%	7%	9%	5%	10%	–2%	5%	–3%	
PHARMACEUTICAL COMPANIES												
Merck & Co.	$ 356	$ 393	$ 426	$ 480	$ 566	$ 669	$ 751	$ 854	$ 998	$1,112	$1,173	11.2%
Bristol-Myers Squibb	301	344	412	474	563	688	789	881	993	1,083	1,128	9.9
Pfizer	230	255	287	336	401	473	531	640	757	863	974	13.0
Eli Lilly	294	341	370	427	466	512	605	703	767	925	955	14.8
Upjohn	218	247	284	314	356	380	407	427	491	549	642	17.8
American Cyanamid	208	232	251	278	314	365	406	460	492	566	596	13.9
Schering-Plough	145	164	175	212	251	298	327	380	426	522	578	13.3
TOTAL	$1,752	$1,976	$2,205	$2,521	$2,917	$3,385	$3,816	$4,345	$4,924	$5,620	$6,046	12.6%
ANNUAL CHANGE	14%	13%	12%	14%	16%	16%	13%	14%	13%	14%	8%	

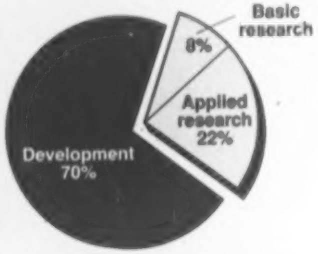
Note: Prior years are not restated to reflect company revisions. **a** For fiscal year ending Sept. 30. **b** Beginning in 1989, excludes Tredegar Industries, spun off in 1989. **c** For fiscal year ending June 30, includes all company-financed R&D but excludes contract R&D; data for Morton Thiokol prior to 1985. **d** Spun off from Union Carbide in 1992. **e** For fiscal year ending Oct. 31. **Source:** Company data

CHEMISTS IN INDUSTRY: Nonmanufacturing firms draw 15%

Industry	% of industrial chemists[a]				Mean salary ($ thousands)[b]		
	All chemists	B.S.	M.S.	Ph.D.	B.S.	M.S.	Ph.D.
MANUFACTURING							
Pharmaceuticals[c]	22%	18%	24%	24%	$49.6	$55.9	$79.1
Specialty chemicals	13	12	12	14	48.9	55.9	70.8
Basic chemicals	5	3	3	7	51.4	55.5	71.2
Plastics	4	3	4	5	49.0	62.7	76.1
Coatings	4	6	4	3	46.9	57.6	66.8
Medical devices	4	3	4	5	43.8	61.8	71.4
Petroleum and natural gas	3	3	2	4	49.1	56.9	79.6
Agricultural chemicals	3	3	4	4	46.9	55.0	72.7
Food	3	4	4	2	44.6	57.2	69.0
Instruments	3	3	3	3	46.4	58.9	65.1
Electronics	2	2	2	3	43.5	56.0	74.3
Aerospace	2	1	2	2	52.4	53.0	71.5
Rubber	2	2	2	1	47.0	57.5	63.3
Soaps and detergents	2	2	—	2	47.0	—	75.0
Metals and minerals	2	3	—	1	43.2	—	69.8
Biochemical products	2	1	2	2	48.2	50.2	70.3
Paper	1	1	1	1	43.6	45.9	67.9
Other	8	8	9	8	43.5	58.3	70.7
NONMANUFACTURING							
Analytical service labs	6	12	7	2	41.3	48.6	59.3
Contract research firms	3	2	3	4	40.5	58.0	65.9
Utilities	1	2	2	—	49.8	56.2	—
Other	5	6	5	4	41.1	56.7	68.0

a Totals may not add up because of rounding. b As of March 1, 1994; to facilitate comparison, mean salaries are adjusted for differences in average length of experience. c Includes personal care products. **Source:** ACS survey

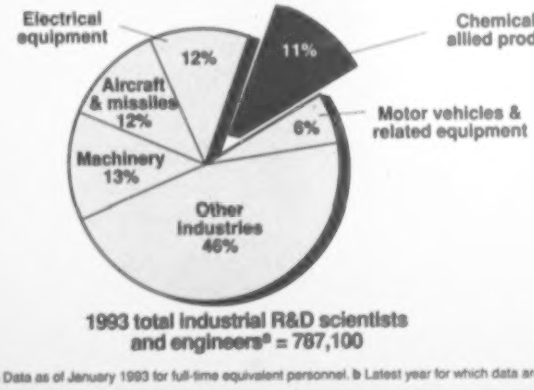
Development accounts for 70% of industrial R&D funds



Estimated total 1993 industrial R&D spending = $126 billion

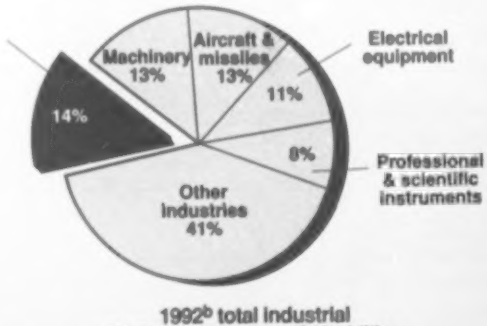
Source: National Science Foundation

Chemical producers employ 11% of industrial scientists and engineers . . .



1993 total industrial R&D scientists and engineers[a] = 787,100

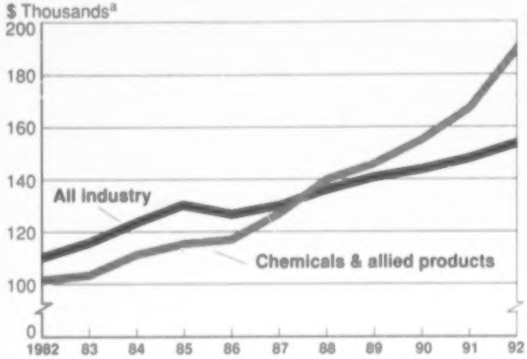
. . . and spend 14% of total industrial R&D funds in the U.S.



1992[b] total industrial R&D expenditures = $121 billion

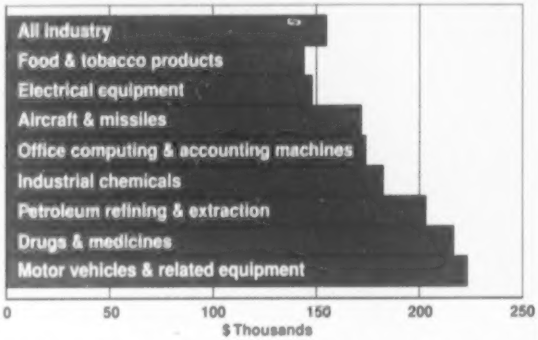
a Data as of January 1993 for full-time equivalent personnel. b Latest year for which data are available. **Source:** National Science Foundation

Cost per R&D scientist in chemical firms has nearly doubled since 1982



a Cost per industrial scientist or engineer. **Source:** National Science Foundation

Auto industry spends the most for its R&D scientists and engineers



a Cost per industrial scientist or engineer. **Source:** National Science Foundation

R&D SCIENTISTS AND ENGINEERS PER 1,000 EMPLOYEES: Drug firms lead in chemical fields

	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Chemicals and allied products	**51**	**54**	**57**	**57**	**70**	**68**	**70**	**72**	**74**	**69**	**76**
Industrial chemicals	44	45	41	39	56	52	55	56	57	60	66
Drugs	74	82	89	81	98	98	99	98	110	95	108
Other chemicals	37	39	51	62	63	61	61	63	61	53	53
Petroleum refining and extraction	**22**	**22**	**22**	**21**	**19**	**20**	**24**	**25**	**25**	**26**	**28**
Machinery	**48**	**57**	**56**	**60**	**64**	**67**	**68**	**76**	**81**	**74**	**74**
Office, computing, and accounting machines	80	88	90	99	107	115	116	133	142	137	139
Electrical Equipment	**55**	**51**	**49**	**53**	**59**	**65**	**70**	**70**	**73**	**67**	**66**
Transportation equipment	**na**	**na**	**na**	**71**	**69**	**68**	**73**	**73**	**72**	**73**	**75**
Motor vehicles and related equipment	31	30	27	28	38	42	41	43	45	49	49
Aircraft and missiles	94	102	110	116	99	91	101	100	96	98	105
ALL INDUSTRY	**33**	**34**	**40**	**43**	**45**	**45**	**47**	**49**	**50**	**50**	**47**

na = not available. **Source:** "Research and Development in Industry," National Science Foundation

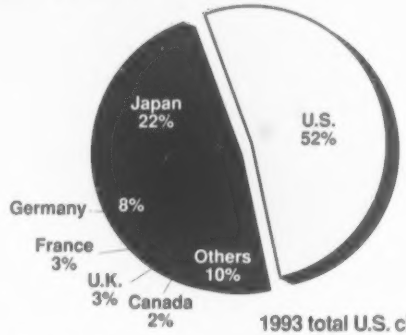
R&D SCIENTISTS AND ENGINEERS IN INDUSTRY: Pharmaceutical firms gain 10%

												% annual change	
Thousands	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1992–93	1983–93
Chemicals and allied products	**67.3**	**69.8**	**71.1**	**75.8**	**75.2**	**75.8**	**77.6**	**78.9**	**78.8**	**85.6**	**89.2**	**4%**	**3%**
Industrial chemicals	26.6	25.6	23.5	24.9	22.4[a]	22.5[a]	23.1[a]	23.0[a]	22.7[a]	29.9	29.6	–1	1
Drugs	28.2	30.8[a]	30.8	31.8	32.6	33.0	34.0	33.5	34.2	38.7	42.6	10	4
Other chemicals	12.1	13.4	16.7	19.1	20.2	20.3	20.5	22.4	21.9	17.0	17.0	0	4
Other industries	**473.6**	**514.3**	**551.4**	**595.2**	**620.6**	**632.8**	**642.6**	**652.0**	**625.3**	**693.7**	**697.9**	**1**	**4**
TOTAL	**540.9**	**584.1**	**622.5**	**671.0**	**695.8**	**708.6**	**720.2**	**730.9**	**704.1**	**779.3**	**787.1**	**1%**	**4%**

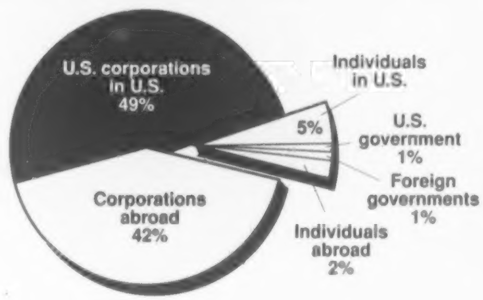
Note: Data as of January of each year for full-time equivalent personnel. **a** C&EN estimates. **Source:** "Research and Development in Industry," National Science Foundation

U.S. Chemical Patents Issued In 1993 Up 4%, Topping 30,000

Nearly half of U.S. chemical patents originate outside the U.S. . . .



. . . and 91% are owned by corporations—both in the U.S. and abroad



1993 total U.S. chemical patents assigned = 30,743

Note: Origin of patent is based on address of inventor whose name is first on patent application. For corporations, it is based on address of company named on patent application.
Source: U.S. Patent & Trademark Office

ORIGIN OF U.S. CHEMICAL PATENTS: South Korea, Taiwan rack up big gains

Number of patents issued[a]	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	% annual change 1992–93	% annual change 1983–93
U.S.	10,564	11,523	11,555	10,528	11,431	11,269	13,847	13,119	14,155	15,508	16,111	4%	4%
Japan	2,830	3,257	3,732	3,641	4,120	4,280	5,447	5,469	5,819	6,257	6,815	9	9
Germany[b]	1,995	2,140	2,180	2,077	2,269	2,340	2,798	2,704	2,670	2,702	2,586	–4	3
France	614	665	716	664	831	800	946	917	1,006	1,013	1,033	2	5
U.K.	702	847	854	713	756	849	1,009	953	970	911	883	–3	2
Canada	267	286	358	276	321	335	461	431	461	538	531	–1	7
Italy	219	259	296	277	288	315	417	408	426	429	494	15	9
Switzerland	434	454	458	413	444	433	504	474	473	427	452	6	0
Netherlands	220	227	198	196	234	236	332	283	337	289	320	11	4
Belgium	94	127	107	110	154	145	189	154	165	176	204	16	8
South Korea	5	10	9	7	11	13	29	52	82	102	164	61	42
Sweden	146	138	182	178	173	159	187	189	156	151	161	7	1
Taiwan	8	10	18	9	13	19	31	52	69	93	147	58	34
Finland	41	57	63	67	79	73	74	115	118	138	109	–21	10
Israel	37	45	37	50	70	63	99	82	87	98	105	7	11
Australia	59	76	69	70	95	85	106	87	124	93	93	0	5
Denmark	40	51	52	50	52	41	78	61	71	81	89	10	8
Austria	63	45	63	55	55	98	100	86	104	112	84	–25	3
Hungary	64	74	68	74	77	54	76	51	62	64	49	–23	–3
Other	234	236	240	219	248	225	490	317	301	302	313	4	3
TOTAL	**18,636**	**20,527**	**21,255**	**19,674**	**21,721**	**21,832**	**27,033**	**26,004**	**27,656**	**29,484**	**30,743**	**4%**	**5%**

Note: Origin of patent is based on address of inventor whose name is first on patent application. **a** Includes patents issued in those technology subclasses that the U.S. Patent & Trademark Office classifies as chemical. **b** Patents prior to October 1990 were issued to West Germany. **Source:** "Technology Assessment and Forecast Report, Chemical Classes," U.S. Patent & Trademark Office

OWNERS OF U.S. CHEMICAL PATENTS: U.S. corporations receive just under half

Number of patents assigned[a]	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	Total 1984–93
U.S.	**12,282**	**12,390**	**11,196**	**12,154**	**12,001**	**14,819**	**14,043**	**15,067**	**16,341**	**16,966**	**137,259**
to U.S. corporations in the U.S.	10,960	11,061	9,970	10,763	10,718	13,210	12,417	13,441	14,483	15,154	122,177
to U.S. government	379	335	293	332	264	306	316	350	418	414	3,407
to individuals in the U.S.	943	994	933	1,059	1,019	1,303	1,310	1,276	1,440	1,398	11,675
Foreign	**8,245**	**8,865**	**8,478**	**9,567**	**9,831**	**12,214**	**11,961**	**12,589**	**13,143**	**13,777**	**108,670**
to corporations abroad	7,521	8,137	7,794	8,808	9,075	11,304	11,077	11,665	12,219	12,917	100,517
to foreign governments	166	161	150	200	170	176	155	201	194	180	1,753
to individuals abroad	558	567	534	559	586	734	729	723	730	680	6,400
TOTAL	**20,527**	**21,255**	**19,674**	**21,721**	**21,832**	**27,033**	**26,004**	**27,656**	**29,484**	**30,743**	**245,929**
% FOREIGN	**40.2%**	**41.7%**	**43.1%**	**44.0%**	**45.0%**	**45.2%**	**46.0%**	**45.5%**	**44.6%**	**44.8%**	**44.2%**

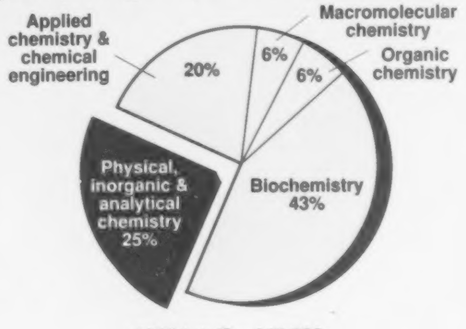
Note: Patent ownership for corporations is based on address of company named on patent application. a Includes patents issued in those technology subclasses that the U.S. Patent & Trademark Office classifies as chemical. **Source:** "Technology Assessment and Forecast Report, Chemical Classes," U.S. Patent & Trademark Office

PATENT ACTIVITY OF U.S. COMPANIES: Drug firms collect more, chemical firms slide

Number of utility patents issued	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	Total 1984–93
CHEMICAL COMPANIES											
DuPont[a]	416	396	371	449	437	495	533	652	648	605	**5,002**
Dow Chemical	328	336	371	469	421	431	400	332	320	328	**3,736**
Dow Corning	52	55	69	58	82	105	122	135	144	93	**915**
Union Carbide	231	242	208	159	141	132	127[b]	131[b]	138[c]	119[d]	**1,628**
Monsanto	138	100	111	91	76	88	84	129	129	103	**1,049**
W. R. Grace	57	45	43	44	61	111	105	121	129	122	**838**
American Cyanamid	111	115	92	107	101	114	136	106	126	135	**1,143**
Olin	112	117	81	58	60	80	74	105	114	72	**873**
Ethyl	76	105	77	48	51	87	108	118	95	88	**853**
Air Products	60	80	61	85	70	119	98	119	90	110	**892**
PPG Industries	137	128	124	118	118	112	100	94	69	83	**1,083**
Nalco	32	32	26	50	52	55	54	49	69	59	**478**
International Specialty Products[e]	19	23	12	15	23	50	42	40	67	71	**362**
Rohm and Haas	37	31	33	22	18	32	32	49	65	116	**435**
Hercules	39	41	43	50	32	47	35	63	38	30	**418**
International Flavors & Fragrances	95	104	76	38	24	31	40	38	25	25	**496**
TOTAL[f]	**1,940**	**1,950**	**1,798**	**1,861**	**1,767**	**2,089**	**2,090**	**2,281**	**2,266**	**2,159**	**20,201**
ANNUAL CHANGE	**13%**	**1%**	**–8%**	**4%**	**–5%**	**18%**	**0%**	**9%**	**–1%**	**–5%**	
DRUG COMPANIES											
Merck	135	105	103	123	125	173	134	152	164	222	**1,436**
Bristol-Myers Squibb	87	110	105	125	120	116	123	124	129	119	**1,158**
Abbott Laboratories	32	36	29	30	39	39	64	79	128	127	**603**
Warner-Lambert	49	73	101	118	113	117	108	120	92	85	**976**
Pfizer	89	72	72	67	63	79	82	91	81	66	**762**
Hoffmann-LaRoche	78	74	84	86	59	93	78	78	72	87	**789**
Eli Lilly	80	107	82	85	68	75	73	66	63	79	**778**
American Home Products	32	49	38	46	69	78	66	46	56	66	**546**
Upjohn	109	66	66	26	15	30	26	23	31	30	**422**
TOTAL[f]	**691**	**692**	**680**	**706**	**671**	**800**	**754**	**779**	**814**	**881**	**7,470**
ANNUAL CHANGE	**22%**	**0%**	**–2%**	**4%**	**–5%**	**19%**	**–6%**	**3%**	**4%**	**8%**	

Note: Includes U.S. chemical and drug companies and U.S. subsidiaries of foreign companies that have received more than 1,000 U.S. patents since 1969. a Includes patents issued to Conoco. b Includes patents issued to Union Carbide Chemicals & Plastics, Union Carbide Chemicals & Plastics Technology, and Union Carbide Industrial Gases Technology. c Patents issued to Union Carbide Chemicals & Plastics Technology and Union Carbide Industrial Gases Technology. d Company data. e Patents were issued to GAF Chemicals from 1983 to 1991. f These totals include patents issued to companies in this table only. **Sources:** "Patenting by Organizations" and "All Technologies Report," U.S. Patent & Trademark Office

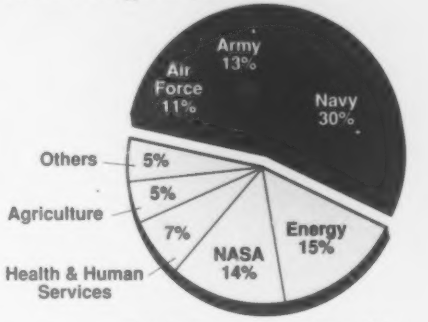
One fourth of chemistry papers are in physical, inorganic, and analytical fields



1993 total[a] = 448,733

[a] Number of abstracts of papers published in *Chemical Abstracts*.
Source: Chemical Abstracts Service

Defense gets more than half of patents issued to U.S. government



Total utility patents issued to U.S. government in 1993 = 1,165

Source: U.S. Patent & Trademark Office

PATENT ACTIVITY OF U.S. GOVERNMENT: Navy has been in forefront since 1990

Number of utility patents issued	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	Total
Defense	653	596	594	525	322	425	498	687	580	629	5,509
Navy	285	248	216	170	103	125	265	381	297	344	2,434
Army	187	205	198	169	104	163	132	171	144	153	1,626
Air Force	181	143	180	186	115	137	101	135	139	132	1,449
Energy	327	293	234	236	224	215	223	195	242	172	2,361
NASA	136	144	93	122	93	127	128	151	151	165	1,310
Health & Human Services	30	35	28	34	27	34	37	48	76	85	434
Agriculture	48	33	32	29	35	43	49	46	53	54	422
Other agencies	41	38	41	35	32	36	48	56	59	60	446
TOTAL	1,235	1,139	1,022	981	733	880	983	1,183	1,161	1,165	10,482

Source: U.S. Patent & Trademark Office

ORIGIN OF CHEMICAL LITERATURE: Russia is fifth largest producer

% of total papers[a]	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
U.S.	27.0%	27.1%	27.0%	27.7%	27.8%	27.4%	27.8%	27.9%	29.2%	27.4%	28.1%
Japan	10.6	10.4	12.1	11.5	11.7	11.5	11.8	12.1	12.5	13.2	13.3
Germany	7.3[b]	7.2[b]	7.4[b]	7.3[b]	7.2[b]	7.5[b]	7.4[b]	7.4[b]	7.3	7.4	7.5
U.K.	5.8	5.6	5.8	5.6	5.7	5.6	5.7	5.5	5.7	5.7	5.7
Russia[c]	—	—	—	—	—	—	—	—	—	2.0	5.4
France	4.1	4.0	4.3	4.3	4.2	4.3	4.2	4.2	4.2	4.4	4.7
China	2.1	2.3	2.6	3.1	3.3	3.5	3.7	4.5	4.0	4.7	4.3
Canada	2.7	2.8	2.9	3.1	3.0	3.1	3.0	3.0	3.0	3.0	3.2
India	3.0	3.2	3.0	3.0	2.3	3.1	2.8	2.9	2.7	2.8	2.6
Italy	2.5	2.5	2.4	2.4	1.7	2.4	2.3	2.3	2.4	2.6	2.6
Spain	0.9	1.0	1.2	1.3	1.4	1.4	1.4	1.5	1.4	1.6	1.7
Netherlands	1.4	1.4	1.4	1.4	1.4	1.5	1.5	1.5	1.5	1.6	1.6
Australia	1.3	1.3	1.4	1.8	1.3	1.3	1.2	1.2	1.2	1.4	1.4
Poland	1.8	1.7	1.7	1.3	1.7	1.7	1.6	1.5	1.5	1.4	1.4
Sweden	1.1	1.2	1.2	1.2	1.2	1.2	1.2	1.1	1.1	1.2	1.2
Switzerland	1.0	1.0	1.1	1.1	1.1	1.1	1.1	1.0	1.1	1.2	1.2
U.S.S.R.	17.0	16.8	14.9	13.0	12.7	13.0	12.7	12.5	11.1	6.5[d]	—
All others	10.4	10.5	9.6	10.9	11.0	10.4	10.6	9.9	10.1	11.9	14.1
TOTAL PAPERS (THOUSANDS)	371.4	380.7	380.1	384.1	386.5	389.7	397.2	394.9	453.6	430.2	448.7

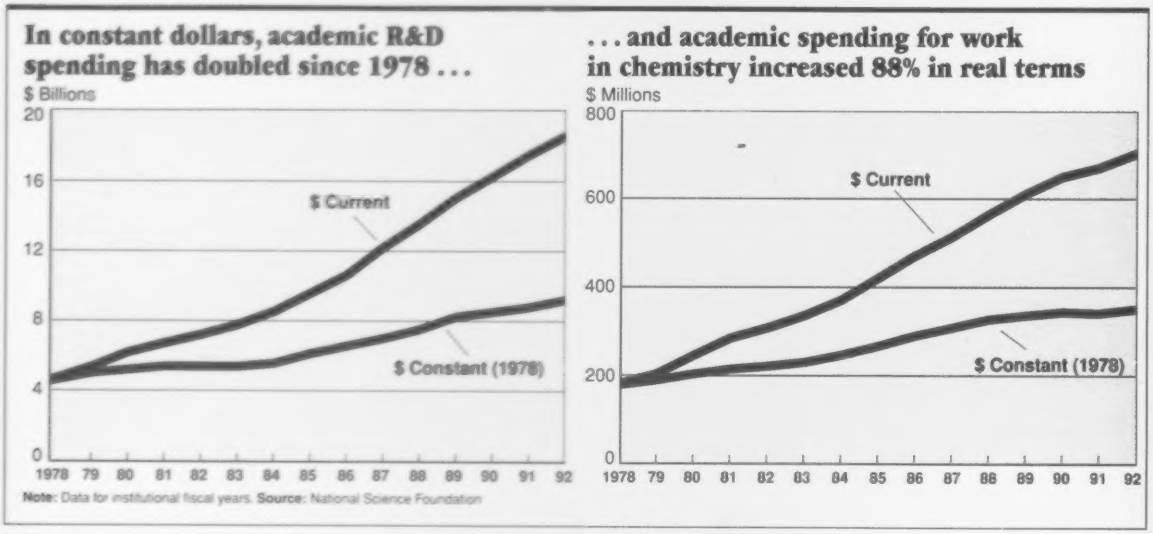
a Source of journal literature abstracted in *Chemical Abstracts* based on first author's address. **b** Combined total for West Germany and East Germany. **c** Data for 1983–91 included in total for U.S.S.R. **d** Papers abstracted in 1992 that indicated U.S.S.R. as author's address. **Source:** Chemical Abstracts Service

ABSTRACTS OF PAPERS IN *CHEMICAL ABSTRACTS*: Biochemistry's share jumps to 43%

	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	Change 1983–93
BIOCHEMISTRY	**38.3%**	**40.5%**	**40.5%**	**40.4%**	**40.5%**	**39.7%**	**39.2%**	**36.9%**	**39.5%**	**39.6%**	**43.0%**	**4.7%**
% of all biochemistry abstracts												
Mammalian hormones	12.9	12.4	12.3	12.5	12.2	12.0	12.0	11.5	12.2	11.7	10.7	–2.2
Mammalian biochemistry	11.1	11.3	11.1	10.8	11.1	10.8	10.7	10.5	12.0	12.3	13.4	2.3
Pharmacology	11.8	11.6	12.3	12.2	12.6	12.7	12.6	11.7	11.4	11.6	10.6	–1.2
Biochemical genetics	3.8	4.2	5.2	6.1	6.7	7.6	7.9	10.1	9.0	7.3	8.8	5.0
Toxicology	8.5	8.0	7.9	7.8	8.3	7.9	7.8	6.7	6.9	6.6	5.9	–2.6
Immunochemistry	4.2	4.8	5.3	6.1	5.8	5.8	6.3	6.8	6.2	7.4	7.8	3.6
Enzymes	6.1	5.8	5.6	5.6	5.4	6.1	6.1	6.1	5.9	5.6	6.1	0
Biochemical methods	4.9	4.9	4.9	5.0	4.8	5.1	5.1	4.7	5.2	5.0	4.5	–0.4
Plant biochemistry	5.9	6.2	5.5	5.2	5.3	5.0	4.6	5.1	5.1	4.7	4.7	–1.2
Microbial biochemistry	5.1	5.2	5.7	5.7	5.1	4.8	5.1	5.4	4.7	5.2	5.1	0
Food and feed chemistry	4.5	4.3	4.2	3.9	3.8	3.5	3.7	3.7	3.6	4.7	4.4	–0.1
Others	21.2	21.3	20.0	19.1	18.9	18.7	18.1	17.7	17.8	17.9	18.0	–3.2
TOTAL	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	—
PHYSICAL, INORGANIC, AND ANALYTICAL CHEMISTRY	**29.6%**	**28.8%**	**29.8%**	**29.8%**	**29.0%**	**28.8%**	**29.0%**	**30.3%**	**28.4%**	**27.7%**	**25.3%**	**–4.3%**
% of all physical, inorganic, and analytical chemistry abstracts												
Spectra	17.6	18.0	18.4	20.0	20.4	20.0	18.1	16.9	18.1	16.8	15.8	–1.8
Nuclear chemistry	22.5	22.2	21.8	19.9	19.5	17.8	19.4	17.1	16.3	17.4	19.8	–2.7
Electric phenomena	10.0	10.8	10.8	10.8	10.9	12.5	13.9	13.2	14.8	14.6	14.7	4.7
General physical chemistry	7.3	6.9	6.9	7.0	7.9	7.2	6.9	7.7	7.3	7.5	7.6	0.3
Analytical chemistry	6.2	6.3	6.1	6.8	5.9	5.7	5.1	7.9	6.4	6.4	6.0	0.2
Crystallography and liquid crystals	8.3	7.8	7.5	7.0	7.1	7.0	7.8	7.3	7.4	7.7	7.2	–1.1
Surface chemistry and colloids	4.3	4.5	4.9	4.7	5.0	5.8	5.7	6.0	6.3	5.9	6.0	1.7
Others	23.8	23.5	23.6	23.8	23.3	24.0	23.1	23.9	23.4	23.7	22.9	0.9
TOTAL	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	—
APPLIED CHEMISTRY AND CHEMICAL ENGINEERING	**19.4%**	**17.6%**	**18.4%**	**18.2%**	**18.0%**	**18.6%**	**18.1%**	**18.2%**	**18.9%**	**20.2%**	**20.0%**	**0.6%**
% of all applied chemistry and chemical engineering abstracts												
Metals and alloys	19.1	18.9	20.0	20.8	20.6	21.7	22.1	24.5	21.2	22.0	22.8	3.7
Water, wastes, and pollution	19.6	21.0	20.2	21.9	20.4	20.4	17.8	18.8	22.2	21.7	20.1	0.5
Ceramics	5.4	5.1	5.6	5.8	6.3	6.7	9.1	9.4	9.1	10.4	8.4	3.0
Fossil fuels, derivatives, and related products	10.3	10.1	10.1	9.0	9.6	8.8	8.7	8.0	8.8	7.8	6.8	–3.5
Unit operations and processes	7.5	7.0	7.5	7.1	9.0	8.0	10.3	9.2	8.3	9.7	10.1	2.6
Pharmaceuticals and pharmaceutical analysis	6.5	7.0	8.0	8.2	7.8	7.6	7.8	8.2	7.6	7.1	8.9	2.4
Mineralogical and geological chemistry	14.1	14.6	12.5	12.0	11.2	11.8	9.3	7.8	10.1	7.4	8.3	–5.8
Others	17.5	16.3	16.1	15.2	15.1	15.0	14.9	14.1	12.7	13.9	14.6	–2.9
TOTAL	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	—
ORGANIC CHEMISTRY	**7.3%**	**7.6%**	**6.4%**	**5.9%**	**6.9%**	**7.3%**	**7.8%**	**8.7%**	**7.6%**	**6.6%**	**5.7%**	**–1.6%**
% of all organic chemistry abstracts												
Physical organic chemistry	30.5	32.0	30.6	27.3	23.9	23.0	25.9	21.2	21.3	21.6	23.4	–7.1
Heterocyclic compounds	16.2	15.6	16.1	15.0	19.9	18.8	16.1	17.4	19.0	18.0	16.0	–0.2
Organometallic and organometalloidal compounds	16.3	17.1	16.2	18.3	16.1	15.7	18.4	20.4	16.6	17.0	19.0	2.7
Carbohydrates	5.8	5.7	5.7	7.8	5.6	8.1	6.5	7.4	8.5	9.3	8.4	2.6
Amino acids, peptides, and proteins	4.5	4.8	4.6	3.9	4.3	5.8	4.5	6.0	7.3	6.7	7.4	2.9
Aromatic compounds	7.1	6.3	6.3	7.3	7.7	7.2	6.9	7.1	6.8	6.4	6.3	–0.8
Biomolecules and their synthetic analogs	4.5	4.4	4.9	5.0	5.8	6.1	5.8	5.9	5.8	5.6	5.4	0.9
Others	15.1	14.1	15.6	15.4	16.7	15.3	15.9	14.6	14.7	15.4	14.1	–1.0
TOTAL	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	—
MACROMOLECULAR CHEMISTRY	**5.4%**	**5.5%**	**4.9%**	**5.7%**	**5.6%**	**5.6%**	**5.9%**	**5.9%**	**5.6%**	**5.9%**	**6.0%**	**0.6%**
% of all macromolecular chemistry abstracts												
Synthetic high polymers	34.4	34.0	34.1	34.1	35.2	34.8	34.4	38.6	39.5	35.8	35.2	0.8
Plastics manufacture and uses	24.4	24.2	25.3	23.8	23.6	23.7	25.1	23.3	25.8	27.6	29.6	5.4
Textiles	7.9	7.3	8.2	8.8	8.1	7.3	7.2	6.7	7.1	6.6	6.4	–1.5
Cellulose, lignin, paper, and other wood products	9.1	9.6	9.1	9.8	8.8	9.6	9.2	7.6	6.3	7.9	7.9	–1.2
Industrial organic chemicals, leather, fats, and waxes	4.8	4.8	4.4	4.6	5.6	6.8	8.1	8.4	5.6	6.0	6.0	1.2
Synthetic elastomers and natural rubber	7.5	7.3	6.8	6.7	7.2	6.7	5.6	4.8	5.6	5.8	4.9	–2.6
Coatings, inks, and related products	6.6	7.8	7.2	7.2	5.8	5.7	5.6	5.2	5.5	5.2	4.6	–2.0
Others	5.3	5.0	4.9	5.0	5.7	5.4	4.8	5.4	4.6	5.1	5.4	0.1
TOTAL	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	—

How to read this table: Using biochemistry as an example, in 1993 43.0% of all the papers abstracted by Chemical Abstracts Service are in the various subdisciplines of biochemistry; 10.7% of all abstracts in biochemistry, in turn, are in the subdiscipline of mammalian hormones, and so on. **Source:** Chemical Abstracts Service

Growth Of Academic R&D Spending Eases Off To 7% In 1992



In constant dollars, academic R&D spending has doubled since 1978 . . .

. . . and academic spending for work in chemistry increased 88% in real terms

Note: Data for institutional fiscal years. **Source:** National Science Foundation

CHARACTER OF ACADEMIC R&D SPENDING: Both basic and applied work grow slowly

$ Millions	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	% annual change 1991–92	% annual change 1982–92
Basic research	$4,878	$5,303	$5,732	$6,555	$ 7,491	$ 8,391	$ 8,892	$ 9,802	$10,680	$11,562	$12,468	8%	10%
Applied research and development	2,445	2,578	2,888	3,131	3,436	3,761	4,571	5,217	5,654	6,075	6,412	6	10
TOTAL	$7,323	$7,881	$8,620	$9,686	$10,927	$12,152	$13,463	$15,019	$16,334	$17,637	$18,880	7%	10%
ANNUAL CHANGE	7%	8%	9%	12%	13%	11%	11%	12%	9%	8%	7%		

Note: Data for institutional fiscal years. **Source:** "Survey of Scientific and Engineering Expenditures at Universities and Colleges," National Science Foundation

SOURCE OF ACADEMIC R&D FUNDS: Institutions themselves provide 19% of R&D money

$ Millions	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	% annual change 1991–92	% annual change 1982–92
Federal government	$4,768	$4,988	$5,430	$6,063	$ 6,710	$ 7,344	$ 8,192	$ 8,997	$ 9,637	$10,226	$11,087	8%	9%
Institutional funds	1,111	1,302	1,411	1,617	1,868	2,169	2,357	2,714	3,033	3,404	3,576	5	12
State and local governments	616	626	690	752	915	1,023	1,106	1,234	1,339	1,484	1,506	1	9
Industry	337	389	475	560	700	790	872	998	1,130	1,210	1,302	8	14
Other sources	491	576	614	694	734	826	936	1,076	1,195	1,313	1,409	7	11
TOTAL	$7,323	$7,881	$8,620	$9,686	$10,927	$12,152	$13,463	$15,019	$16,334	$17,637	$18,880	7%	10%

Note: Data for institutional fiscal years. **Source:** "Survey of Scientific and Engineering Expenditures at Universities and Colleges," National Science Foundation

FIELDS OF ACADEMIC R&D SPENDING: Chemistry growing more slowly than science overall

$ Millions	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	% annual change 1991–92	% annual change 1982–92
ALL SCIENCES	**$6,282**	**$6,760**	**$7,388**	**$8,268**	**$ 9,286**	**$10,260**	**$11,367**	**$12,621**	**$13,671**	**$14,730**	**$15,798**	**7%**	**10%**
Life sciences	4,017	4,305	4,711	5,279	5,890	6,528	7,257	8,082	8,748	9,497	10,228	8	10
Physical sciences	823	900	1,001	1,148	1,287	1,398	1,554	1,649	1,809	1,945	2,058	6	10
Physics	367	417	474	551	631	673	740	785	842	872	915	5	10
Chemistry	308	335	372	421	470	513	565	610	651	671	701	4	9
Environmental sciences	557	616	645	705	775	839	894	1,014	1,080	1,130	1,249	11	8
Psychology and social sciences	484	481	504	541	632	689	765	874	964	1,046	1,153	10	9
Computer sciences	149	187	224	281	321	372	409	472	514	554	556	0	14
Mathematical sciences	96	106	123	128	152	177	199	214	221	230	247	7	10
Others	156	165	180	186	229	257	289	316	335	328	307	–6	7
ENGINEERING	**1,041**	**1,121**	**1,232**	**1,418**	**1,641**	**1,892**	**2,096**	**2,398**	**2,663**	**2,907**	**3,082**	6	11
Chemical	84	91	102	116	132	148	163	194	219	244	262	7	12
TOTAL	**$7,323**	**$7,881**	**$8,620**	**$9,686**	**$10,927**	**$12,152**	**$13,463**	**$15,019**	**$16,334**	**$17,637**	**$18,880**	**7%**	**10%**
ANNUAL CHANGE	**7%**	**8%**	**9%**	**12%**	**13%**	**11%**	**11%**	**12%**	**9%**	**8%**	**7%**		

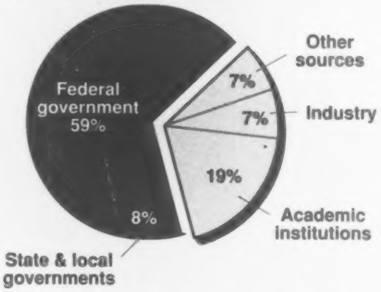
Note: Data for institutional fiscal years. **Source:** "Survey of Scientific and Engineering Expenditures at Universities and Colleges," National Science Foundation

FEDERALLY FINANCED R&D SPENDING AT UNIVERSITIES: Physical sciences get 13% of total

$ Millions	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	% annual change 1991–92	% annual change 1982–92
ALL SCIENCES	**$4,060**	**$4,250**	**$4,641**	**$5,197**	**$5,733**	**$6,230**	**$6,961**	**$7,614**	**$8,114**	**$ 8,592**	**$ 9,332**	**9%**	**9%**
Life sciences	2,502	2,586	2,830	3,188	3,493	3,836	4,326	4,783	5,077	5,407	5,893	9	9
Physical sciences	650	699	782	890	982	1,051	1,157	1,197	1,314	1,383	1,476	7	9
Physics	307	343	390	453	510	535	580	605	651	668	701	5	9
Chemistry	230	247	279	313	338	368	403	423	445	447	476	6	8
Environmental sciences	391	426	446	474	517	546	589	661	691	708	799	13	7
Psychology and social sciences	250	237	241	260	287	293	329	368	394	444	500	13	7
Computer sciences	107	139	163	196	233	257	289	322	340	369	377	2	13
Mathematical sciences	72	76	92	97	114	132	150	156	160	170	183	8	10
Others	88	87	87	92	107	115	121	127	138	111	104	–6	2
ENGINEERING	**704**	**733**	**789**	**867**	**978**	**1,113**	**1,230**	**1,383**	**1,524**	**1,635**	**1,755**	7	10
Chemical	50	53	60	65	73	77	86	101	111	118	126	7	10
TOTAL	**$4,764**	**$4,983**	**$5,430**	**$6,064**	**$6,711**	**$7,343**	**$8,191**	**$8,997**	**$9,638**	**$10,227**	**$11,087**	**8%**	**9%**
ANNUAL CHANGE	**4%**	**5%**	**9%**	**12%**	**11%**	**9%**	**12%**	**10%**	**7%**	**6%**	**8%**		

Note: Data for institutional fiscal years. **Source:** "Survey of Scientific and Engineering Expenditures at Universities and Colleges," National Science Foundation

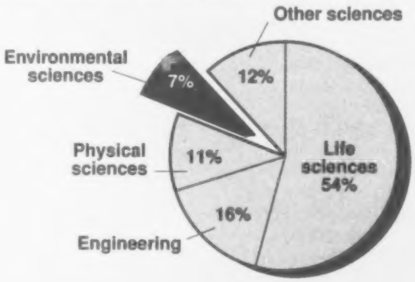
Government bodies supply 67% of academic R&D funds



1992 academic R&D expenditures = $18.9 billion

Source: National Science Foundation

Environmental sciences account for 7% of academic R&D efforts



1992 academic R&D expenditures = $18.9 billion

Source: National Science Foundation

SCHOOLS SPENDING MOST ON CHEMICAL R&D: Stanford, Maryland join top 10

Rank								1992		% annual change	
1992	1991	$ Thousands	1987	1988	1989	1990	1991	Total spending	% federal funds	1991–92	1987–92
1	1	U of Texas, Austin	$ 11,420	$ 10,943	$ 11,484	$ 13,259	$ 16,513	$ 16,021	54%	–3%	7%
2	5	Harvard U	8,895	9,886	11,856	13,114	12,384	14,103	88	14	10
3	2	Massachusetts Inst. of Technology	11,471	13,287	15,031	17,109	16,426	13,999	89	–15	4
4	4	U of California, Berkeley	12,490	14,285	12,663	13,804	13,906	13,835	87	–1	2
5	3	California Inst. of Technology	10,870	9,931	9,235	10,667	13,931	12,647	87	–9	3
6	8	U of California, Los Angeles	10,099	9,519	9,855	11,217	10,519	12,137	89	15	4
7	10	Pennsylvania State U	6,072	7,739	8,616	9,148	9,635	11,719	59	22	14
8	12	Stanford U	8,916	10,547	10,098	9,693	8,882	10,846	78	22	4
9	6	Cornell U	8,397	10,472	10,217	10,042	10,825	10,550	84	–3	5
10	17	U of Maryland, College Park	9,258	8,545	9,732	10,977	8,415	9,991	47	19	2
		Total, first 10 institutions	$ 97,888	$105,154	$108,787	$119,030	$121,436	$125,848	76%	4%	5%
11	7	U of Pennsylvania	6,741	7,292	7,760	8,077	10,633	9,812	82	–8	8
12	13	U of Wisconsin, Madison	6,984	7,282	8,326	8,937	8,878	9,804	71	10	7
13	28	Georgia Inst. of Technology	4,889	5,989	5,380	5,215	6,796	9,656	56	42	15
14	9	U of Massachusetts[a]	7,589	5,280	2,988	9,245	9,684	9,583	56	–1	5
15	11	U of Illinois, Urbana-Champaign	9,035	8,647	9,208	9,230	9,457	9,439	72	0	1
16	14	U of California, San Diego	5,179	6,780	6,487	8,120	8,811	9,076	86	3	12
17	15	Purdue U	7,092	8,615	8,769	8,672	8,690	8,879	78	2	5
18	23	Indiana U	6,181	7,991	7,927	7,344	7,324	8,853	70	21	7
19	16	Princeton U	6,477	8,087	8,873	9,099	8,663	8,557	70	–1	6
20	25	Ohio State U	5,755	7,568	6,771	6,225	6,178	8,289	76	34	8
		Total, first 20 institutions	$163,810	$178,685	$181,276	$199,194	$206,550	$217,796	74%	5%	6%
21	20	Rutgers, State U of New Jersey	3,913	5,926	7,905	7,812	7,818	8,263	73	6	16
22	22	Yale U	5,538	6,869	5,915	6,037	7,587	7,974	85	5	8
23	18	Texas A&M U	7,462	8,785	9,808	8,046	8,201	7,903	53	–4	1
24	30	Wayne State U	3,278	4,582	5,557	5,455	6,458	7,756	30	20	19
25	21	Northwestern U	6,095	6,644	7,661	7,219	7,781	7,651	70	–2	5
26	33	U of Notre Dame	5,550	7,004	6,660	6,348	6,170	7,274	90	18	6
27	24	Virginia Polytechnic Inst. & State U	4,190	4,735	5,155	6,321	7,157	7,178	41	0	11
28	27	U of Colorado	5,118	5,637	6,587	6,041	6,863	6,895	80	0	6
29	19	Arizona State U	3,586	4,306	5,260	7,967	8,054	6,755	65	–16	14
30	35	U of Utah	4,846	4,600	5,653	5,089	6,101	6,697	78	10	7
		Total, first 30 institutions	$213,386	$237,773	$247,437	$265,529	$278,740	$292,142	72%	5%	6%
31	38	U of Washington	3,655	4,338	5,192	6,057	5,789	6,538	61	13	12
32	43	U of Southern California	3,311	3,832	4,374	5,667	5,510	6,337	92	15	14
33	40	U of North Carolina, Chapel Hill	3,471	4,476	5,171	5,310	5,613	6,306	84	12	13
34	41	U of California, Irvine	3,541	4,534	3,910	4,835	5,546	6,237	91	12	12
35	32	U of Oregon	4,462	5,550	5,501	6,760	6,211	6,076	73	–2	6
36	42	U of Arizona	3,441	3,934	4,532	5,034	5,531	6,030	66	9	12
37	31	Columbia U, main division	6,715	4,605[b]	4,721[b]	5,858	6,305	5,985	97	–5	–2
38	50	U of Michigan	3,276	3,879	3,788	3,735	5,031	5,970	69	19	13
39	34	U of Minnesota	5,426	5,232	5,863	6,663	6,160	5,952	85	–3	2
40	51	U of Pittsburgh	5,105	5,598	5,736	5,832	4,826	5,876	84	22	3
		Total, first 40 institutions	$255,789	$283,751	$296,225	$321,280	$335,262	$353,449	74%	5%	7%
41	36	U of Rochester	3,545	4,437	4,762	6,537	6,067	5,871	92	–3	11
42	46	U of Florida	5,690	5,030	5,061	5,396	5,153	5,847	50	13	1
43	58	Emory U	2,333	2,770	3,581	4,228	4,269	5,646	84	32	19
44	29	Johns Hopkins U	5,593	5,211	5,152	5,435	6,564	5,356	93	–18	–1
45	49	Georgetown U	2,735	2,878	3,904	3,860	5,039	5,350	77	6	14
46	48	U of Kansas	2,803	3,845	4,952	5,450	5,059	5,254	36	4	13
47	47	U of Virginia	4,169	4,153	5,096	5,281	5,089	5,225	80	3	5
48	63	Rensselaer Polytechnic Inst.	2,511	3,737	4,156	4,551	3,811	5,214	48	37	16
49	61	U of Alabama, Huntsville	1,396	1,493	2,972	4,317	4,021	5,157	89	28	30
50	44	U of Georgia	2,239	3,531	4,091	4,453	5,508	5,042	44	–8	18
		Total, first 50 institutions	$288,803	$320,836	$339,952	$370,788	$385,842	$407,411	73%	6%	7%
		NATIONAL TOTAL	$513,116	$565,318	$609,534	$650,926	$670,963	$701,216	68%	5%	6%

Note: Data for institutional fiscal years. A number of institutions have developed or are developing new computer systems and methodologies that enable them to report more accurately the total cost of science and engineering research. Comparing 1992 data with those reported in earlier years may not be appropriate in some areas. **a** 1992 figures are for Amherst campus only. **b** Estimated. **Source:** "Survey of Scientific and Engineering Expenditures at Universities and Colleges," National Science Foundation

SCHOOLS WITH MOST FEDERAL SUPPORT FOR CHEMICAL R&D: Harvard moves into first place

Rank 1992	Rank 1991	$ Thousands	1987	1988	1989	1990	1991	1992	% annual change 1991–92	% annual change 1987–92
1	4	Harvard U	$ 8,309	$ 9,272	$ 10,594	$ 11,585	$ 10,972	$ 12,387	13%	8%
2	1	Massachusetts Inst. of Technology	10,656	11,987	13,333	15,129	14,549	12,384	–15	3
3	2	U of California, Berkeley	11,160	12,998	11,540	12,219	12,210	12,008	–2	1
4	3	California Inst. of Technology	9,922	8,769	7,459	8,629	12,006	10,970	–9	2
5	5	U of California, Los Angeles	9,414	8,885	9,024	10,216	9,327	10,841	16	3
6	6	Cornell U	6,753	8,269	7,458	7,211	8,365	8,852	6	6
7	9	U of Texas, Austin	6,405	6,443	6,120	6,723	7,881	8,700	10	6
8	10	Stanford U	7,918	9,423	8,878	8,839	7,452	8,414	13	1
9	7	U of Pennsylvania	5,653	6,337	7,046	7,330	8,168	8,059	–1	7
10	8	U of California, San Diego	4,599	6,161	5,757	7,422	7,949	7,799	–2	11
		Total, first 10 institutions	$ 80,789	$ 88,544	$ 87,209	$ 95,303	$ 98,879	$100,414	2%	4%
11	12	Pennsylvania State U	4,915	5,957	6,515	6,429	6.630	6,972	5	7
12	18	U of Wisconsin, Madison	4,718	4,939	5,505	6,041	5,739	6,929	21	8
13	11	Purdue U	5,978	7,120	7,102	6,893	7,086	6,909	–2	3
14	14	U of Illinois, Urbana-Champaign	6,306	6,193	6,566	6,563	6,484	6,804	5	2
15	13	Yale U	4,909	5,927	5,011	5,256	6,521	6,752	4	7
16	20	U of Notre Dame	5,158	6,557	5,983	5,667	5,599	6,582	18	5
17	31	Ohio State U	4,517	5,437	4,445	4,152	4,844	6,300	30	7
18	28	Indiana U	4,923	6,354	6,127	5,225	5,173	6,157	19	5
19	24	Rutgers, State U of New Jersey	2,525	3,442	6,572	6,016	5,426	5,993	10	19
20	17	Princeton U	5,064	5,812	5,681	6,104	5,794	5,952	3	3
		Total, first 20 institutions	$129,802	$146,282	$146,716	$153,649	$158,175	$165,764	5%	5%
21	23	U of Southern California	2,903	3,568	3,986	5,358	5,427	5,826	7	15
22	16	Columbia U, main division	6,625	4,246[a]	4,344[a]	5,540	5,944	5,785	–3	–3
23	27	U of California, Irvine	3,386	4,376	3,685	4,437	5,226	5,682	9	11
24	26	U of Massachusetts[b]	5,036	3,296	1,326	5,494	5,300	5,522	4	2
25	25	U of Colorado	4,402	4,603	5,418	5,218	5,422	5,494	1	5
26	41	Georgia Inst. of Technology	2,565	3,574	3,020	2,941	3,902	5,426	39	16
27	19	U of Rochester	3,275	3,936	4,327	5,998	5,650	5,402	–4	11
28	21	Northwestern U	4,641	4,955	5,577	5,465	5,462	5,372	–2	3
29	30	U of North Carolina, Chapel Hill	3,153	4,193	4,534	4,651	4,980	[illegible]281	6	11
30	33	U of Utah	4,194	3,614	3,872	3,746	4,688	5,225	11	4
		Total, first 30 institutions	$169,982	$186,643	$186,805	$202,497	$210,176	$220,779	5%	5%
31	29	U of Minnesota	4,395	4,156	5,054	5,857	5,004	5,062	1	3
32	15	Johns Hopkins U	5,116	4,830	4,824	4,994	6,044	4,992	–17	0
33	39	U of Pittsburgh	4,028	4,803	4,558	4,721	3,958	4,959	25	4
34	47	Emory U	2,093	2,362	2,719	3,509	3,290	4,752	44	18
35	35	U of Maryland, College Park	4,073	3,793	3,844	4,774	4,566	4,687	3	3
36	44	U of Alabama, Huntsville	na	1,059	2,414	3,880	3,610	4,591	27	na
37	43	Arizona State U	2,317	2,813	3,172	3,626	3,696	4,414	19	14
38	32	U of Oregon	3,579	4,519	4,435	5,182	4,751	4,411	–7	4
39	34	U of Chicago	6,499	7,235	8,621	8,524	4,597	4,235	–8	–8
40	37	U of Virginia	3,281	3,419	4,165	4,038	4,072	4,191	3	5
		Total, first 40 institutions	$205,363	$225,632	$230,611	$251,602	$253,764	$267,073	5%	5%
41	36	Texas A&M U	4,019	4,945	4,408	3,716	4,395	4,187	–5	1
42	46	U of Michigan	2,615	3,310	3,022	2,786	3,423	4,138	21	10
43	38	Georgetown U	2,155	2,148	3,113	3,088	3,963	4,110	4	14
44	42	U of Washington	2,287	2,904	3,756	4,139	3,796	4,011	6	12
45	45	U of Arizona	2,499	2,885	3,044	3,210	3,580	3,969	11	10
46	49	U of California, Santa Barbara	3,526	3,196	3,242	3,869	3,201	3,835	20	2
47	50	Colorado State U	3,273	4,280	3,457	2,998	3,146	3,794	21	3
48	48	Rockefeller U	3,247	3,082	3,713	4,331	3,289	3,295	0	0
49	60	U of Tennessee system	1,737	2,541	2,985	2,441	2,272	3,171	40	13
50	40	State U of New York, Stony Brook	2,930	3,460	3,610	3,816	3,940	3,129	–21	1
		Total, first 50 institutions	$233,651	$258,383	$264,961	$285,996	$288,769	$304,712	6%	5%
		NATIONAL TOTAL	$367,765	$402,876	$422,609	$444,899	$447,306	$476,266	6%	5%

Note: Data for institutional fiscal years. A number of institutions have developed or are developing new computer systems and methodologies that enable them to report more accurately the total cost of science and engineering research. Comparing 1992 data with those reported in earlier years may not be appropriate in some areas. **a** Estimated. **b** 1992 figures are for Amherst campus only. **na** = not available. **Source:** "Survey of Scientific and Engineering Expenditures at Universities and Colleges," National Science Foundation

SCHOOLS SPENDING MOST ON CHEMICAL ENGINEERING R&D: Top five spend 20% of total

Rank						1992		% annual change	
1992	1991	$ Thousands	1989	1990	1991	Total spending	% federal funds	1991–92	1989–92
1	1	Massachusetts Inst. of Technology	$ 13,493	$ 13,456	$ 16,972	$ 13,007	64%	–23%	–1%
2	3	Texas A&M U	4,159	6,017	9,974	12,352	16	24	44
3	2	U of Tennessee system	1,115	935	10,010	9,518	89	–5	104
4	5	U of Minnesota	8,403	7,817	8,540	9,416	66	10	4
5	6	Case Western Reserve U	3.378	3.665[a]	8,145	9,344	52	15	40
6	4	U of Texas, Austin	6,109	6,025	9,387	7,816	46	–17	9
7	31	U of Oklahoma	2,189	1,594	2,160	7,275	33	237	49
8	7	North Carolina State U, Raleigh	3,304	4,421	6,081	5,804	36	–5	21
9	10	U of Delaware	3,147	3,826	4,899	5,175	27	6	18
10	8	Johns Hopkins U	4,842	4,580	5,103	5,158	90	1	2
11	9	U of Wisconsin, Madison	3,839	4,363	4,903	5,054	46	3	10
12	11	Auburn U	2,217	3,259	3,619	3,995	17	10	22
13	54	Colorado School of Mines	na	738	1,399	3,794	46	171	na
14	na	Brigham Young U	2,867	na	na	3,774	72	na	10
15	18	U of California, Santa Barbara	1,880	2,280	3,025	3,701	80	22	25
16	14	Columbia U, main division	5,308	4,262	3,230	3,673	41	14	–12
17	16	Stanford U	2,939	3,130[b]	3,151	3,525	73	12	6
18	13	Rensselaer Polytechnic Inst.	1,477	2,017	3,297	3,509	48	6	33
19	25	U of Houston	2,015	2,870	2,496	3,360	40	35	19
20	10	Louisiana State U system	2,396	2,714	3,006	3,261	25	8	11
21	22	Georgia Inst. of Technology	2,124	5,382	2,710	3,197	56	18	15
22	na	U of Dayton	12	80	0	3,196	81	na	543
23	20	Lehigh U	2,742	3,067	2,883	3,114	13	8	4
24	15	Princeton U	2,367	2,981	3,207	3,033	42	–5	9
25	29	Oklahoma State U	370	4,028	2,261	3,011	62	33	101
		Total, first 25 institutions	$ 82,692	$ 93,507	$120,458	$138,062	51%	15%	19%
		NATIONAL TOTAL	$185,087	$206,172	$238,553	$262,195	56%	10%	12%

Note: Data for institutional fiscal years. A number of institutions have developed or are developing new computer systems and methodologies that enable them to report more accurately the total cost of science and engineering research. Comparing 1992 data with those reported in earlier years may not be appropriate in some areas. **a** Estimated. **b** Imputed. Institution was not among top 100 spenders of engineering funds. **na** = not available. **Source:** "Survey of Scientific and Engineering Expenditures at Universities and Colleges," National Science Foundation

SCHOOLS WITH MOST FEDERAL SUPPORT FOR CHEMICAL ENGINEERING R&D: MIT slips

Rank							% annual change	
1992	1991	$ Thousands	1989	1990	1991	1992	1991–92	1989–92
1	2	U of Tennessee system	$ 178	$ 303	$ 8,522	$ 8,434	–1%	262%
2	1	Massachusetts Inst. of Technology	9,359	9,279	9,605	8,289	–14	–4
3	3	U of Minnesota	5,279	5,249	5,562	6,194	11	5
4	5	Case Western Reserve U	2,104	2,004	4,295	4,827	12	32
5	4	Johns Hopkins U	4,352	4,171	4,501	4,650	3	2
6	6	U of Texas, Austin	2,253	2,388	3,406	3,610	6	17
7	12	U of California, Santa Barbara	1,580	1,764	2,315	2,958	28	23
8	–	U of Dayton	10	67	0	2,852	na	558
9	10	Brigham Young U	2,290	2,242	2,336	2,736	17	6
10	11	New Mexico State U	1,482	35	2.322	2.693	16	22
11	7	Stanford U	2,564	2,701[a]	2,484	2,557	3	0
12	50	U of Oklahoma	505	1,594	633	2,393	278	68
13	8	U of Wisconsin, Madison	2,096	2,407	2,463	2,338	–5	na
14	14	California Inst. of Technology	1,635	1,477	1,911	2,205	15	10
15	19	U of Alabama, Huntsville	1.019	1,836	1,461	2,110	44	27
16	9	North Carolina State U, Raleigh	861	1,764	2,422	2,071	–14	34
17	15	Texas A&M U	706	922	1,703	1,971	16	41
18	16	Oklahoma State U	84	2,660	1,645	1,877	14	182
19	20	U of Michigan	1,482	1,686	1,447	1,860	29	8
20	17	Georgia Inst. of Technology	1,192	3,035	1,556	1,796	15	15
21	54	Colorado School of Mines	na	321	1,556	1,727	11	na
22	13	Cornell U	1,250	1,340	2,084	1,720	–17	11
23	18	Rensselaer Polytechnic Inst.	606	971	1,358	1,681	24	41
24	60	Columbia U, main division	3,059	2,265	424	1,520	258	–21
25	40	U of Pittsburgh	794	760	937	1.479	58	23
		Total, first 25 institutions	$46,740	$53,241	$ 66,948	$ 76,548	14%	18%
		NATIONAL TOTAL	$92,947	$99.937	$114,310	$126,473	11%	11%

Note: Data for institutional fiscal years. A number of institutions have developed or are developing new computer systems and methodologies that enable them to report more accurately the total cost of science and engineering research. Comparing 1992 data with those reported in earlier years may not be appropriate in some areas. **a** Imputed. Institution was not among top 100 recipients of engineering funds. **na** = not available. **Source:** "Survey of Scientific and Engineering Expenditures at Universities and Colleges," National Science Foundation

TOP 10 UNIVERSITIES IN R&D SPENDING: Top 10 spend 20% of all R&D funds

Rank 1992	Rank 1991	$ Millions, 1992	Physical sciences	Chemistry[a]	Engineering	Environmental sciences	Life sciences	Math & computer sciences	Other sciences	Total
1	1	Johns Hopkins U	$ 130.1	$ 5.4	$ 225.4	$ 41.1	$ 226.2	$ 86.8	$ 25.9	$ 735.5
2	2	U of Michigan	23.9	6.0	64.9	20.5	196.0	24.5	63.4	393.2
3	6	Stanford U	75.7	10.8	107.5	6.9	155.7	13.3	8.9	368.0
4	4	U of Wisconsin, Madison	35.2	9.8	46.3	21.7	202.2	8.4	38.8	352.6
5	5	Massachusetts Inst. of Technology	95.9	14.0	141.0	13.1	38.1	16.4	20.0	324.5
6	3	U of Minnesota	16.2	6.0	26.1	11.8	224.2	18.4	20.3	317.0
7	9	U of Washington	17.6	6.5	18.4	59.4	192.5	9.8	15.8	313.5
8	8	Texas A&M U	16.9	7.9	77.5	65.7	123.0	4.7	17.5	305.3
9	7	Cornell U	44.6	10.6	44.0	5.1	164.0	27.2	14.5	299.4
10	10	U of California, San Francisco	0	0	0	0	295.8	0	0	295.8
		TOTAL, FIRST 10 INSTITUTIONS	$ 456.1	$ 77.0	$ 751.1	$ 245.3	$ 1,817.7	$209.5	$ 225.1	$ 3,704.8
		TOTAL, ALL INSTITUTIONS	$2,057.8	$701.2	$3,082.3	$1,248.8	$10,227.8	$802.7	$1,460.3	$18,879.7

Note: Data for institutional fiscal years. [a] Included in physical sciences. **Source:** "Survey of Scientific and Engineering Expenditures at Universities and Colleges," National Science Foundation

TOP 10 UNIVERSITY R&D CENTERS: About 40% of their effort goes to physical sciences

Rank 1992	Rank 1991	$ Millions, 1992	Physical sciences	Engineering	Math & computer sciences	Environmental sciences	Life sciences	Other sciences	Total
1	2	Jet Propulsion Lab	$ 92.6	$ 443.0	$516.1	$ 85.4	$ 0	$ 0	$1,137.1
2	1	Lawrence Livermore National Lab	388.6	459.0	143.3	31.9	32.9	0	1,055.7
3	3	Los Alamos National Lab	421.6	367.0	94.0	7.1	66.7	54.6	1,011.0
4	4	Argonne National Lab	119.5	205.9	6.9	90.4	17.9	0	440.6
5	5	Lincoln Lab	69.5	254.8	37.7	2.3	0	0	364.3
6	6	Brookhaven National Lab	210.7	48.0	1.3	11.2	25.7	1.3	298.2
7	7	Lawrence Berkeley Lab	164.6	10.5	3.1	13.7	39.7	7.8	239.4
8	8	Fermi National Accelerator Lab	197.7	0	0	0	0	0	197.7
9	9	Stanford Linear Accelerator Center	117.7	0	0	0	0	0	117.7
10	10	Plasma Physics Lab	110.2	0	0	0	0	0	110.2
		TOTAL, FIRST 10 INSTITUTIONS	$1,892.7	$1,788.2	$802.4	$242.0	$182.9	$63.7	$4,971.9
		TOTAL, ALL INSTITUTIONS	$2,017.1	$1,797.2	$838.2	$339.4	$191.2	$65.5	$5,248.6

Note: Data for university-administered, federally funded R&D centers. **Source:** "Survey of Scientific and Engineering Expenditures at Universities and Colleges," National Science Foundation

UNIVERSITY SPENDING FOR RESEARCH EQUIPMENT: Chemistry accounts for 7% of total

	1985		1991		1992		% annual change 1991–92		% annual change 1985–92	
$ Millions	Total	Federal funds	Total	Federal funds	Total	Federal funds	Total	Federal funds	Total	Federal funds
ALL SCIENCES	$547.0	$340.6	$ 792.7	$472.9	$ 813.1	$489.0	3%	3%	6%	5%
Life sciences	282.5	157.0	411.0	217.9	430.6	228.7	5	5	6	6
Physical sciences	141.8	113.2	190.6	139.5	200.0	151.6	5	9	5	4
Physics	71.2	60.2	85.4	66.7	91.0	73.0	7	9	4	3
Chemistry	53.9	41.4	70.3	47.5	71.9	50.8	2	7	4	3
Environmental sciences	47.8	32.4	70.6	43.6	78.6	52.0	11	19	7	7
Mathematical and computer sciences	41.5	21.0	69.9	50.2	55.6	36.2	–20	–28	4	8
Others	33.4	17.0	50.6	21.7	48.3	20.5	–5	–6	5	3
ENGINEERING	124.4	78.3	233.9	134.6	238.9	126.1	2	–6	10	7
Chemical	11.4	6.7	20.0	9.8	20.3	10.1	2	3	9	6
TOTAL	$671.4	$418.9	$1,026.6	$607.5	$1,052.0	$615.1	2%	1%	7%	6%

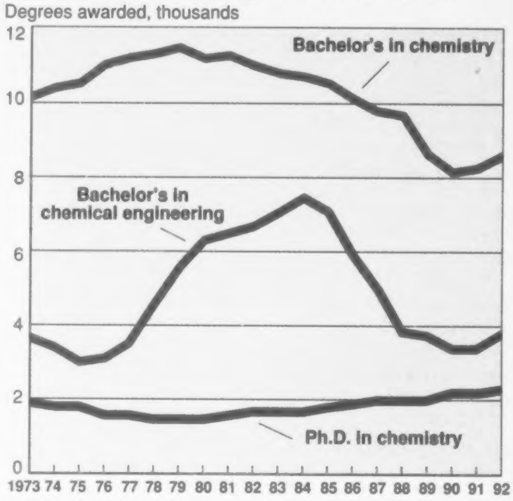
Note: Data for institutional fiscal years. **Source:** "Survey of Scientific and Engineering Expenditures at Universities and Colleges," National Science Foundation

CHEMICAL DEGREES: Number of bachelor's degrees in chemical engineering up 9%

Academic year	Degrees awarded in chemistry			Degrees awarded in chemical engineering		
	Bachelor's	Master's	Ph.D.	Bachelor's	Master's	Ph.D.
1973	10,125	2,225	1,882	3,578	1,051	397
1974	10,438	2,125	1,828	3,399	1,044	400
1975	10,549	1,986	1,822	3,070	990	346
1976	11,022	1,783	1,621	3,140	1,031	308
1977	11,215	1,767	1,568	3,524	1,086	291
1978	11,315	1,886	1,521	4,569	1,235	259
1979	11,509	1,757	1,516	5,588	1,149	304
1980	11,232	1,723	1,545	6,320	1,270	284
1981	11,347	1,654	1,622	6,527	1,267	300
1982	11,025	1,618	1,722	6,740	1,285	311
1983	10,796	1,622	1,746	7,185	1,368	319
1984	10,704	1,667	1,744	7,475	1,514	330
1985	10,482	1,719	1,789	7,146	1,544	418
1986	10,116	1,754	1,908	5,877	1,361	446
1987	9,661	1,738	1,976	4,983	1,184	497
1988	9,052	1,708	1,995	3,917	1,088	579
1989	8,625	1,774	2,037	3,683	1,093	602
1990	8,132	1,682	2,183	3,430	1,035	562
1991	8,321	1,165	2,238	3,444	903	611
1992	8,641	1,780	2,280	3,754	956	590

Note: Data collected from degree-granting institutions.
Source: National Center for Education Statistics

Chemistry Ph.D. degrees creep up 2%



Note: Academic years. **Source:** National Center for Education Statistics

GRADUATE SCIENCE STUDENTS: Engineering attracts three times as many as physical sciences

Thousands	1982	1983	1984[a]	1985[a]	1986[a]	1987[a]	1988	1989	1990	1991	1992	% annual change 1991–92	% annual change 1982–92
ALL SCIENCES	**255.9**	**257.3**	**258.1**	**263.1**	**266.6**	**269.8**	**272.8**	**279.3**	**290.3**	**300.3**	**313.5**	4%	2%
Psychology and social sciences	117.0	113.0	110.9	111.7	111.8	114.4	115.9	120.3	126.7	132.8	139.6	5	2
Mathematical and computer sciences	37.0	41.0	43.3	47.2	49.2	50.4	51.2	51.6	54.1	54.8	56.8	4	4
Biological sciences	46.1	45.8	45.9	46.2	46.9	46.9	47.7	49.0	50.1	51.9	54.4	5	2
Biochemistry	4.1	4.2	4.5	4.7	4.9	4.8	4.9	5.1	5.1	5.2	5.4	4	3
Physical sciences	28.2	29.5	30.1	31.0	32.2	32.7	33.0	33.6	34.1	34.8	35.5	2	2
Chemistry	17.0	17.8	17.8	18.3	18.7	18.8	18.6	18.8	19.1	19.4	19.9	3	2
Physics	10.3	10.8	11.3	11.7	12.4	12.8	13.3	13.7	13.9	14.1	14.3	1	3
Earth, atmospheric, and ocean sciences	15.2	15.6	15.7	15.6	15.2	14.5	14.1	13.8	14.2	14.7	15.6	6	0
Agricultural sciences	12.4	12.4	12.2	11.4	11.3	10.9	10.9	11.0	11.1	11.3	11.6	3	–1
ALL ENGINEERING	**83.9**	**91.1**	**92.8**	**96.2**	**102.1**	**104.1**	**103.1**	**104.2**	**107.7**	**113.3**	**118.0**	4	3
Chemical	7.2	7.6	7.4	7.2	7.0	7.1	6.6	6.5	6.7	7.1	7.4	4	0
Metallurgical and materials	3.1	3.4	3.7	3.9	4.2	4.4	4.3	4.6	4.9	5.2	5.5	6	6
TOTAL	**339.8**	**348.4**	**350.9**	**359.3**	**368.7**	**373.9**	**375.9**	**383.5**	**398.0**	**413.6**	**431.5**	4%	2%
ANNUAL CHANGE	**2%**	**3%**	**1%**	**2%**	**3%**	**1%**	**1%**	**2%**	**4%**	**4%**	**4%**		

Note: Data for all institutions, includes full- and part-time graduate students. a Includes estimated data for master's-granting institutions, which were surveyed on a sample basis from 1984 through 1987. **Source:** "Survey of Graduate Students and Postdoctorates in Science and Engineering," National Science Foundation

FOREIGN GRADUATE STUDENTS: Total drops to 25% of all grad students

	1987a		1988		1989		1990		1991		1992		% annual change	
	Thousands	% of total	Thousands	% of total	Thousands	% of total	Thousands	% of total	Thousands	% of total	Thousands	% of total	1991–92	1987–92
ALL SCIENCES	48.07	26%	50.97	27%	53.20	28%	56.16	28%	57.88	28%	58.54	27%	1%	4%
Psychology and social sciences	13.47	19	14.19	20	14.12	19	14.58	18	14.87	18	14.91	17	0	2
Mathematical and computer sciences	11.96	47	12.48	44	12.97	44	13.89	46	14.05	45	14.37	45	2	4
Physical sciences	10.03	35	10.48	37	11.14	38	11.69	40	11.90	40	11.93	39	0	4
Chemistry	4.94	30	5.32	33	5.72	35	6.14	37	6.35	38	6.30	37	–1	5
Physics	4.89	43	4.96	43	5.23	43	5.33	44	5.30	43	5.37	42	1	2
Biological sciences	8.01	21	9.00	23	10.01	25	10.68	26	11.60	27	11.82	27	2	8
Biochemistry	1.21	26	1.33	29	1.51	31	1.63	34	1.72	35	1.68	33	–2	7
Agricultural sciences	2.63	33	2.64	29	2.63	30	2.86	32	2.86	31	2.83	30	–1	1
Earth, atmospheric, and ocean sciences	1.97	19	2.18	21	2.33	23	2.46	24	2.60	25	2.69	24	3	6
ALL ENGINEERING	28.04	45	29.54	47	30.33	47	31.53	48	33.69	48	34.25	46	2	4
Chemical	2.31	41	2.39	45	2.61	49	2.76	51	2.98	51	2.93	49	–2	5
Metallurgical and materials	1.61	47	1.66	48	1.83	49	1.95	50	1.99	49	2.00	47	1	4
TOTAL	76.11	31%	80.51	32%	83.53	32%	87.69	33%	91.57	33%	92.79	25%	1%	4%
ANNUAL CHANGE	5%		6%		4%		5%		4%		1%			

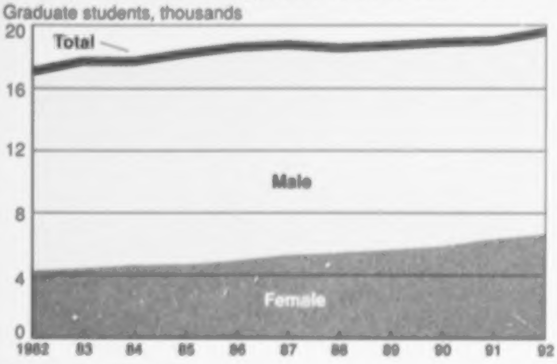
Note: The percent of total is the percent of all full-time graduate students in each area who are not U.S. citizens. a Includes estimated data for master's-granting institutions, which were surveyed on a sample basis in 1987. **Source:** "Survey of Graduate Students and Postdoctorates in Science and Engineering," National Science Foundation

POSTDOCTORAL APPOINTEES: Nearly one fourth work in chemistry or biochemistry

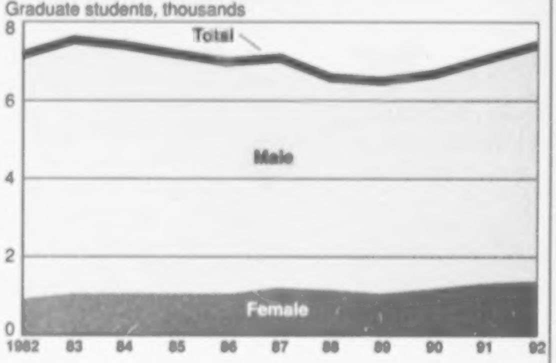
	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	% annual change	
												1991–92	1982–92
ALL SCIENCES	13,694	14,556	14,974	15,519	16,449	17,327	18,004	18,970	19,873	20,660	21,677	5%	5%
Biological sciences	7,756	8,355	8,707	9,136	9,701	10,364	10,686	11,449	11,963	12,550	13,287	6	6
Biochemistry	1,684	1,748	1,783	1,858	1,985	2,113	2,078	2,216	2,174	2,123	2,161	2	3
Physical sciences	4,281	4,444	4,386	4,495	4,808	4,941	5,178	5,348	5,557	5,678	5,772	2	3
Chemistry	2,805	2,973	2,906	2,995	3,149	3,234	3,420	3,456	3,629	3,647	3,573	–2	2
Physics	1,326	1,350	1,320	1,320	1,494	1,548	1,578	1,677	1,716	1,798	1,954	9	4
Psychology and social sciences	803	783	752	846	841	834	816	901	899	879	928	6	1
Earth, atmospheric, and ocean sciences	335	415	488	375	417	420	499	459	607	645	709	10	8
Agricultural sciences	279	307	375	373	409	441	454	512	529	575	634	10	9
Mathematical and computer sciences	240	252	266	294	273	327	371	301	318	333	350	5	4
ALL ENGINEERING	978	1,101	1,194	1,353	1,398	1,443	1,684	1,908	1,940	2,255	2,344	4	9
Chemical	174	198	245	273	295	310	423	466	551	578	554	–4	12
Metallurgical and materials	166	204	168	245	250	283	325	323	365	394	458	16	11
TOTAL	14,672	15,657	16,168	16,872	17,847	18,770	19,688	20,878	21,813	22,915	24,024	5%	5%
ANNUAL CHANGE	–1%	7%	3%	4%	6%	5%	5%	6%	4%	5%	5%		

Note: Doctorate-granting institutions. **Source:** "Survey of Graduate Students and Postdoctorates in Science and Engineering," National Science Foundation

In chemistry, women account for nearly one third of graduate students . . .



. . . in chemical engineering, they account for less than one fifth



Source: National Science Foundation

CHEMICAL DOCTORATE DEGREES: U.S. citizens' share falls to 59% from 76% in 1982

	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	% annual change 1991–92	% annual change 1982–92
U.S. CITIZENS	**1,285**	**1,355**	**1,332**	**1,345**	**1,320**	**1,381**	**1,377**	**1,298**	**1,398**	**1,350**	**1,320**	**–2%**	**0%**
By sex													
Male	1,076	1,121	1,083	1,084	1,044	1,085	1,072	956	1,046	1,014	964	–15	–1
Female	209	234	249	261	276	296	305	342	352	336	356	6	5
By ethnic group													
White	1,191	1,248	1,189	1,219	1,182	1,243	1,235	1,167	1,249	1,201	1,184	–1	0
Asian	35	39	50	57	56	49	48	42	54	62	63	2	6
Hispanic	15	19	26	14	24	40	43	40	50	39	34	–13	9
Black	10	11	18	19	13	11	17	20	14	18	13	–28	3
Native American	nr	3	3	2	5	6	5	5	3	9	6	–33	—
Unknown	34	35	46	34	40	32	29	24	28	21	20	–5	–5
NON-U.S. CITIZENS	**348**	**352**	**381**	**417**	**486**	**490**	**516**	**546**	**629**	**799**	**834**	**4**	**9**
By sex													
Male	293	295	319	335	381	400	417	417	489	625	618	–1	8
Female	55	57	62	82	105	90	99	129	140	174	216	18	14
By ethnic group													
Asian	236	224	255	257	315	326	365	416	463	597	631	6	10
White	75	80	67	92	94	101	96	78	97	125	120	–4	5
Hispanic	9	16	26	28	23	24	22	18	24	27	28	4	12
Black	16	16	24	23	21	16	16	18	14	25	24	–4	4
Unknown	12	16	9	17	33	23	17	16	31	25	21	–16	6
CITIZENSHIP UNKNOWN	**47**	**52**	**52**	**74**	**97**	**104**	**122**	**126**	**73**	**44**	**68**	**55%**	**4%**
TOTAL	**1,680**	**1,759**	**1,765**	**1,836**	**1,903**	**1,975**	**2,015**	**1,970**	**2,100**	**2,193**	**2,222**	**1%**	**3%**
ANNUAL CHANGE	**6%**	**5%**	**0%**	**4%**	**4%**	**4%**	**2%**	**–2%**	**7%**	**4%**	**1%**		

Note: Data were collected from individual graduates. nr = none reported. **Source:** "Survey of Earned Doctorates," National Science Foundation

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CHEMICAL & ENGINEERING NEWS

C&EN

AUGUST 29, 1994

NEW SYNTHETIC METHODS YIELD COMPLEX LINKED-RING MOLECULES PAGE 28

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RUBBER CHEMICALS

Additives strive to meet more demanding product performance
Page 11

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CHEMICAL & ENGINEERING NEWS

C&EN

AUGUST 29, 1994

NEWS OF THE WEEK

- Linus Pauling, who won the Nobel Prize in Chemistry for his work on chemical bonds and the Nobel Peace Prize for his efforts to end nuclear testing, is dead at 93. **Page 4**
- An explosion and fire at Shell olefins plant in Norco, La., will further pinch U.S. ethylene supplies; no one was seriously injured. **Page 5**
- Monsanto announces $1 million contest for development of practical method to recover ammonia from waste streams containing organics. **Page 5**
- The 208th national meeting of the American Chemical Society attracted about 13,500 attendees to its myriad activities. **Page 6**
- Top German chemical firms post better results for first-half 1994, spurred mainly by improved sales and profits abroad. **Page 7**
- Synthesis of $C_{30}H_{12}$—"buckybowl"— by flash pyrolysis achieved by Louisiana State University researchers. **Page 7**
- Chlorinated organic chemicals can be used and discharged without adverse effects, says a study commissioned by Chemical Manufacturers Association, fueling ongoing controversy. **Page 8**

COVER: Photo courtesy of Goodyear

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BUSINESS

Companies benefit from cooperative R&D agreements with federal labs, but lack of federal funding and issues such as patent rights and competitiveness may slow collaborative work. **Page 18**

The market for purified terephthalic acid continues to grow, and producers respond with expansions that will boost global capacity 62% by 1998. **Page 19**

GOVERNMENT

Senate appropriations for federal R&D are up 1% from the Administration's requested budget—NIST would receive major increase, with NSF, NIH, and Defense seeing more modest gains. **Page 23**

EPA proposes a threshold exemption for reporting releases and transfers of toxic chemicals in an attempt to reduce paperwork for the agency and chemical industry. **Page 25**

SCIENCE POLICY

Japan has a new national concern—the drying up of the pipeline of new technical professionals—as its youth display a lack of interest in science and technology. **Page 26**

SCIENCE/TECHNOLOGY

New template-directed syntheses of elegant linked-ring macromolecules called catenanes are leading researchers to propose that preparation of interlocking ring polymers may be near. **Page 28**

Iron phthalocyanine complexes encapsulated in zeolite crystals are the basis for a new synthetic catalyst system that mimics the structure, function, and activity of P450 enzymes. **Page 34**

EDUCATION

Technological advances and new instructional methods leading to changes in undergraduate chemistry curricula were the focus of a recent ACS Division of Chemical Education conference. **Page 35**

COVER STORY

Demands for tougher, more resistant, better performing rubber products, as well as health and environmental concerns, drive development of high-performance rubber chemicals and additives. Page 11

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Chemical & Engineering News

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LETTERS

Regulation for the public good

Several important pieces of environmental legislation are up for renewal by Congress. These include the Clean Water Act, the Safe Drinking Water Act, the Endangered Species Act, and Superfund. These acts should be strengthened, rather than weakened, as suggested by some businesses, municipalities, and landowners who wish to continue to externalize some of their costs at the expense of the general public. Your report on the Business Roundtable (C&EN, July 4, page 15) puts it in this group.

Regulations usually result from failures in our market-based system that lead to disasters and abuses that have an impact on the good of the general public. There have been three incidents in northern Delaware in the past two months. A vessel broke allowing the release of about 500 lb of chlorine into the air, two tanks of oily ballast water were destroyed by fire at the Star Enterprise refinery, and the Salem nuclear power plant had an emergency alert.

These incidents could have been much more serious. Should the regulations covering these businesses be beefed up to prevent recurrences? If businesses and municipalities were self-policing and avoided such problems, there would be much less inclination to regulate.

The report of the Business Roundtable deals in generalities, using words that imply that the present system is costly and inefficient. It tells what industry is spending to comply but doesn't mention what is needed to correct the problems. (It doesn't mention the many jobs and businesses that have been created by the cleanup.) The laws have encouraged innovation to find less polluting processes. The main loss in innovation has been the curtailment of exploratory research as a result of corporate downsizing. The lack of growth may be due to failure to modernize. An example is lack of adoption of continuous casting by the U.S. steel industry some years ago.

The concept of cost-benefit analysis has been twisted to make environmental compliance look very expensive. The costs to the general public are often left out of industry's calculations. The loss of jobs when the fishery downstream is destroyed, a child's asthma from air pollution, the loss of biodiversity from the extinction of species, decreased crop yields, and the loss of recreation close to home need to be included. However, it is very difficult to put dollar signs on some of these.

The report also mentions unfunded mandates imposed by federal laws on state and local governments. All levels have a shared responsibility to fund environmental legislation. Perhaps we should return to the funding formula used in the pre-Reagan years. In a case of illnesses of thousands of people from Cryptosporidium in the Milwaukee water supply, it would seem that the local citizens should be happy to put up the money for an improved water supply. Regulation at the federal level has the advantage of providing a level playing field, so that a business can't compete more successfully by moving to a locality where pollution laws are weaker.

No one would say that we have found the best way to regulate for the good of the general public. Market-oriented regulations and performance standards are being implemented. One of the most successful approaches has been the law requiring that industries report their toxic emissions. When a company sees its name in the local paper as the number-one polluter in the area, it finds time to fix those leaky valves and, sometimes, to reexamine the whole process in the plant to look for possible improvements.

Many companies and municipalities make an earnest effort to clean up. However, there are others that have "greened" primarily in their public relations departments.

Albert S. Matlack
Hockessin, Del.

Put DEA in charge of tobacco

The Commissioner of the Food & Drug Administration has been suggesting that tobacco be placed under FDA control as a drug (C&EN, June 27, page 5), and a letter (C&EN, July 25, page 5) suggests that regulation of tobacco be transferred from

Correction

- Aug. 22, page 7: In the discussions between American Cyanamid and SmithKline Beecham, Cyanamid's prescription drug and consumer-brand businesses and SmithKline's vaccine and animal health businesses were the businesses under consideration to be swapped.

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Rubber Chemicals And Additives Adapt To Changing Demands

■ ***Customers' calls for rubber products with improved durability and heat resistance lead to better rubber chemicals***

Marc S. Reisch,
C&EN Northeast News Bureau

Rubber products today must last longer under higher temperature conditions than they did just a few years ago. They must perform under greater environmental stress and still look good. And they must compete against plastics and other materials.

But while a compounder's choice of any number of synthetic or natural rubber polymers will influence the ultimate durability and performance of a rubber article, such as a tire or an automotive radiator hose, processing chemicals and additives are decisive elements. Without processing chemicals and reinforcing additives, such as carbon black and silica, rubber manufacture as we know it would not be possible.

Rubber chemicals initiate the cross-linking of both natural and synthetic elastomers in a process (generally requiring sulfur) called vulcanization. Some additives directly affect a rubber article's durability, by protecting it from the degrading effects of oil, moisture, air, or ozone. Other additives lubricate rubber for processing, allow for easier release from molding equipment, or initiate the formation of air bubbles in a compound to produce sponge rubber for gaskets.

Trends affecting rubber chemicals have led to the development of compounds that reduce worker exposure to suspected nitrosamine carcinogens, allow the production of more heat-resistant compounds, and enhance tire durability. As a class, rubber chemicals are a disproportionately small part of a rubber article. Rubber compounders use an average of just 4.4 lb of rubber-processing chemicals per 100 lb of rubber.

On the other hand, rubber compounders may load rubber for tire use with the reinforcing additive—carbon black—at rates as high as 75 lb per 100 lb of rubber. Carbon black acts not just as a filler; it is also a performance additive that imparts strength and toughness to a tire. Manufacturers have developed new grades of carbon black for use under higher temperatures than previously were customary, for instance, for under-the-hood automotive hoses. Tire makers are also substituting various amounts of silica for carbon black, as they construct passenger car tires intended to last 80,000 or even 100,000 miles.

Rubber products can be separated into two major categories, with sales valued at more than $18 billion: fabricated rubber products and tires. The U.S. International Trade Administration (ITA) estimates the value of synthetic rubber produced in the U.S. in 1993 at about $4.5 billion, but the estimated value of fabricated rubber products produced from those synthetics with the addition of natural rubber is $6.7 billion. The category includes not only elastomeric roofing, rubberized fabrics, geomembranes to line landfills, and conveyor belts but also a significant number of automotive-related items such as belts, hoses, and gaskets. ITA values 1993 tire shipments at $11.4 billion.

Goodyear technician studies tread design.

Much of the increase in value added to raw synthetic and natural rubber to make rubber products results from the physical process of compounding and then forming rubber in tire molds and hose and sheet extruders. Many rubber items contain reinforcing steel or polyester fiber, which adds performance—as well as cost—to an item's manufacture. But the addition of rubber-processing chemicals provides advantages out of proportion to their cost. Industry sources estimate that U.S. compounders spend about $500 million on rubber chemicals annually. Thus, rubber chemicals, which not only affect rubber's performance but also allow cross-

Rubber requires additives for best performance

Crude rubber has few applications in its raw state and requires a number of chemical additives and fillers to modify its hardness, strength, and toughness. It also needs additives to increase resistance to heat, abrasion, oil, ozone, oxygen, and solvents. The additives fall into 10 categories:

Accelerators: **Used with sulfur to shorten rubber cure time.**

Antioxidants: **Improve service life of rubber exposed to air, heat, and light.**

Antiozonants: **Protect cured rubber against degradation from atmospheric ozone.**

Blowing agents: **Allow formation of cellular structures to produce sponge rubber.**

Fillers: **Materials such as clay, whiting, and diatomaceous earth used to add weight and bulk.**

Pigments: **Impart color to rubber articles.**

Reinforcing agents: **Add strength and toughen rubber. Carbon black is the most important reinforcing agent.**

Retarders: **Lengthen time before rubber cures to prevent "scorching"—that is, premature curing.**

Softeners and plasticizers: **Shorten mixing time and help disperse compounding agents.**

Vulcanizing agents: **Initiate crosslinking of polymer chains to cure rubber.**

linking of rubber compounds, represent less than 3% of the $18 billion value of rubber products.

C&EN estimates that the domestic rubber industry will use about 304 million lb of organic processing chemicals in 1994, compared with 297 million lb in 1993. Of 1994 consumption, 59% by weight will be antioxidants and antiozonants, 34% will be vulcanization agents and accelerators, and 7% will be other chemicals such as blowing agents. Industry sources suggest that rubber processors worldwide use 1.4 billion lb of rubber chemicals, worth some $2.4 billion. Industry overcapacity, they say, had led to lower prices of rubber-processing chemicals worldwide.

More than 20 U.S. companies produce about 200 or so substances that over 1,000 U.S. rubber product manufacturing plants use to make rubber compounds. Seven of those rubber chemical producers are diversified manufacturers, which account for more than 80% of U.S. rubber chemical sales. The seven companies are St. Louis-based Monsanto, which probably is the largest U.S. rubber chemicals producer, with about 35% of the market; Uniroyal (Middlebury, Conn.); Goodyear (Akron, Ohio); BF Goodrich (Akron); Miles (Pittsburgh), the U.S. affiliate of Germany's Bayer; R. T. Vanderbilt (Norwalk, Conn.); and Akzo Nobel (Chicago). The largest U.S. rubber chemical producers—Monsanto and Uniroyal—are also global producers, with products manufactured and shipped worldwide. Several other companies also participate in the U.S. rubber chemicals market: Phillips (Bartlesville, Okla.), Elf Atochem (Philadelphia), Cytec (West Paterson, N.J.), Hampshire Chemical (Lexington, Mass.), and Sartomer (Exton, Pa.).

A host of distributors also serves rubber compounders. R. T. Vanderbilt is not only a manufacturer but also a major distributor. C. P. Hall, based in Chicago, is a large distributor and rubber chemicals producer. Over the past few years, Hall has acquired Morton Rubber Chemicals and product lines from Union Carbide and American Cyanamid. Other large distributors include Akrochem Corp. (Akron, Ohio), Harwick Chemical (Akron), and H. M. Royal (Trenton, N.J.)

According to Ron Walters, Monsanto's worldwide marketing director for its rubber and process chemicals business, Monsanto has been manufacturing rubber chemicals since 1929. Today, the company has plants in the U.S., Canada, South America, Europe, and Asia. A separate unit, Monsanto Instruments & Equipment, based in Akron, makes rubber test equipment for the industry. Walters believes that Monsanto has an edge over other rubber chemicals makers, because the company's rubber test equipment is so widely used as a standard for measurement in the industry.

Walters says Monsanto has the largest capacity for making rubber chemicals in the U.S. but, like its competitors, does not specify Monsanto's capacity. The company produces four major categories of rubber chemicals: accelerators, antidegradants, vulcanization inhibitors, and specialty additives. Accelerators produced by Monsanto include sulfenamides, sulfenimides, and thiazoles.

A few years ago, most producers of rubber vulcanization accelerators dropped many of the sulfenimides they produced, because they react with airborne nitrogen oxides to become potentially carcinogenic nitrosamines. With prompting from the German government, the rubber chemicals industry was concerned that concentrations of nitrosamines would not only be too high in rubber factory air but also could affect air quality in tire warehouses and in car trunks where the spare tires sit. Monsanto's Santocure TBSI is the only sulfenimide now widely used in the rubber industry, says Walters. TBSI is a unique vulcanization accelerator, he says; it performs like a secondary-amine-based accelerator but without the potential to form nitrosamines.

Another important product, says Walters, is a hybrid cross-linker, hexamethylene-1,6-bis(thiosulfate), which helps rubber products retain their physical properties during both cure and service and also promotes bonding between rubber and brass-plated steel. Sold under the tradename of Duralink HTS, the product is widely used in tire manufacture.

As the U.S. economy has grown over the past two years, Walters says Monsanto has seen a slight increase in the sales of its rubber-processing chemicals in the U.S. But although many observers might think that increased auto production would necessarily increase rubber and rubber chemicals consumption, Walters says that it is actually more important to track how much people drive their cars and trucks. In the U.S., Europe, and other developed parts of the world, "it's all the same to us," says Walters; new car tires and older car replacement tires use the same amount of rubber chemicals, he points out.

New motor vehicle production (which in the U.S. was up 17% to more than 7 million units at the end of July, compared with the same period a year ago) means something more in the

Asia-Pacific region. There, most people are acquiring cars for the first time, says Walters. Market growth for rubber and rubber chemicals in Asia-Pacific slowed from double-digit growth before 1990 to high single-digit growth more recently. In contrast, the U.S. is now in the low single-digit growth area, market growth having been static between 1990 and 1991.

Degussa photo

Consumption of rubber chemicals worldwide also has been affected by the falloff in demand from countries that once were part of the Soviet Union or its close allies in Eastern Europe. Those countries once consumed 15% of world rubber, Walters estimates, but now they consume only about 5%. As a result, some rubber chemicals produced in countries such as the Czech and Slovak Republics are going into the world market.

Because of that new competition, and the decline in demand for rubber from the Commonwealth of Independent States and Eastern Europe, Walters acknowledges that worldwide there is more supply than demand for both rubber and rubber chemicals, and as a result, prices of rubber chemicals have declined. Because of some recent strengthening in rubber demand in the U.S. and signs of economic recovery in Europe, Walters says Monsanto has announced price increases for accelerators, quinoline-based antiozonants, and other products. He hopes the increases will stick.

Anthony M. Luxedor, rubber chemicals marketing director for BF Goodrich, says the company has been squeezed between higher prices for raw materials and an inability to pass along increases in rubber chemical prices to customers. Goodrich produces rubber chemicals only in the U.S. but sells them to other parts of the world. Luxedor attributes the price problem to competition not just from Central Europe but also from producers in Western Europe who have sought to sell products overseas during the recent recession in Europe.

Tire distributor employees check inventory (left), and Goodyear engineer measures tire pressure (below).

Goodrich produces a number of amine- and phenolic-based antioxidants, used primarily to protect rubber from the degrading effects of heat. It produces phenolic phosphite to stabilize raw rubber during processing, protecting it from crusting on the surface. And the company also produces various thiazole and sulfenamide accelerators. The latter is not a contributor to the problem of airborne nitrosamines.

Uniroyal's Peter D. Welch, rubber chemicals business director, also acknowledges pressure from the automotive market to reduce costs, thereby pushing rubber chemical prices down. However, volume sales have been "not bad" over the past year. Demand for rubber chemicals is doing "rather well" in North America. Welch ranks Uniroyal second among U.S. rubber chemical producers, after Monsanto, and either second or third worldwide, after Monsanto and about on a par with Bayer.

Welch says that Uniroyal produces accelerators (based on aldehyde amines, dithiocarbamates, thiazoles, thiurams, and others); secondary-amine-based, phenolic-based, and other antioxidants; and nitrogen-based blowing agents. The company recently signed a letter of intent to expand in Eastern Europe via the purchase of Istrachem in Slovakia. Uniroyal's sales of rubber chemicals are split between the U.S. and overseas, Welch says, and markets outside the U.S. are growing faster. As a result, the company plans more efforts overseas. "Our customers are globalizing and we have to do the same," he says.

Uniroyal recently added a new thiuram-based accelerator, which reduces nitrosamine formation, to its line of rubber chemicals. Along with sulfenamide and thiazole accelerators, Uniroyal's new accelerator, tradenamed Benzyl Tuex, replaces tetramethyl thiuram monosulfide, tetramethyl thiuram disulfide, and tetraethyl thiuram disulfide, which form detectable amounts of nitrosamines. Benzyl Tuex also helps prevent the breakdown of natural cured rubber, says Welch.

Akzo Nobel is planning to introduce a rubber chemical that also prevents rubber breakdown. The company's marketing director for the rubber chemicals group, Bob Bradley, says that in September Akzo Nobel hopes to introduce a new product to prevent the delamination of rubber tread from tire carcasses. Delamination is an annoying and frequently dangerous breakdown of rubber under heat and stress. Bradley hopes that the new rubber chemical will reduce or eliminate the rubber tread that litters interstate highways. He declines to describe the nature of the new proprietary product, which he calls an "antireversion agent." The product—tradenamed Perkalink 900—promises not only to help maintain rubber cure but also to allow increased manufacturing productivity through higher temperature curing.

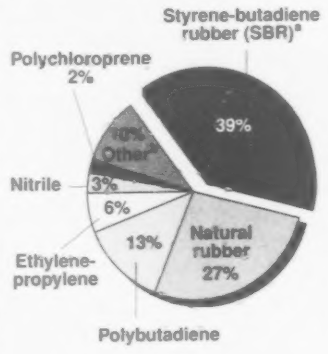
In addition to its planned offering of Perkalink 900, Akzo Nobel offers a broad range of rubber chemicals. Worldwide, Bradley says Akzo Nobel probably ranks fourth among rubber chemicals suppliers in the U.S., after Monsanto, Bayer, and Uniroyal. Akzo Nobel produces cross-linking peroxides and insoluble sulfur (which aids in curing rubber) in the U.S. The company offers a range of accelerators including thiazole-, sulfenamide-, thiuram-, and dithiocarbamate-based products and antidegradants including diamine- and diphenylamine-based products from its overseas plants.

Bradley says the 2-mercaptobenzothiazole accelerator plant the company originally hoped to build in Le Moyne, Ala., by 1991, is still in the planning stages. Engineering for the plant is almost complete, and the company plans to apply for environmental permits in September or October.

Peroxide-cured rubber is seeing increased demand from auto manufacturers, notes Bradley. As car manufacturers extend warranties, they need hoses and rubber for under-the-hood applications that last longer in engines that run hotter and at higher revolutions per minute than they did a number of years ago. As a result, more peroxide-cured polychloroprene is in demand for auto use, he says. However, industry sources estimate that only about 5% of rubber is cured with peroxide. The bulk is still cured with sulfur.

According to Goodyear's applications R&D section head, Don E. Miller, Goodyear produces rubber chemicals in the U.S. and Europe that it uses for in-house tire and rubber product manufacture and also sells to customers. The company produces antioxidants and antiozonants. It has produced accelerators and vulcanizing agents, but it is in the process of shutting down part of its Niagara Falls, N.Y., complex where those compounds are produced because of environmental problems.

SBR is most widely used type of elastomer

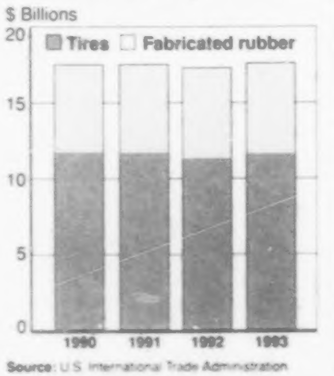


1993 total U.S. rubber consumption = 8.4 billion lb

a Includes solid, latex, and carboxylated forms.
b Includes isoprene, copolymers of isobutylene and isoprene, and other rubber. **Source:** International Institute of Synthetic Rubber Producers

Miller says the company's *p*-phenylenediamine grades of antioxidants and antiozonants are industry mainstays, because they provide resistance to flex fatigue in tires and conveyor belts and add to product longevity at attractive prices. Sold under the tradename of Wingstay 100 and 200, they also are good heat stabilizers, he says. Goodyear also produces phenol-, diphenylamine-, and modified thioester-based antidegradants.

Tires continue to dominate U.S. rubber shipments



Source: U.S. International Trade Administration

Some companies produce more limited lines of rubber chemicals. Phillips and Elf Atochem both produce mercaptans. Compounds like *n*-dodecyl mercaptan and *tert*-dodecyl mercaptan help control viscosity in synthetic rubber such as styrene-butadiene and polychloroprene, says Phillips specialty chemicals manager Mary Jane Hagenson. Elf Atochem also produces a line of accelerators based on alkylphenol disulfide. Vicki L. Quinn, Elf Atochem marketing manager, says that the company's alkylphenol disulfide product line lends heat- and age-resistant properties to rubber, particularly chlorobutyl rubber.

Cytec, the recent spin-off from American Cyanamid, sells a line of hexamethylmethoxymelamine under the tradename Cyrez; the product helps bond brass-coated steel to rubber, is a reinforcing agent in tire sidewalls, and aids rubber-to-rubber adhesion between tire layers. Cytec business manager Gene Cirilis says that Cyrez is an advanced resin technology that competes with cobalt and cobalt salts with high sulfur content for wire adhesion in rubber.

Sartomer, the resins division of French chemical company Total, sells a line of acrylic materials used in peroxide-cured rubber. Al Tuccio, Sartomer's marketing manager based at the company's U.S. sales office in Exton, Pa., says that as automotive manufacturers insist on better performance, demand for rubber cured with peroxide and acrylic coagents will grow. Most of the acrylic coagents supplied by Sartomer are based on trimethylolpropane trimethacrylate.

The coagents not only enhance rubber-to-metal adhesion but also improve compression set, hardness, dynamic properties such as resilience, and stress-strain properties. They also provide additional benefits, he says, in the form of water, oil, and chemical resistance. Tuccio admits, though, that acrylic coagents as well as peroxide cure agents are more expensive than sulfur-based systems and, as a result, have met some resistance in the marketplace.

Besides the rubber chemicals used to enhance natural and synthetic rubber performance, carbon black, produced largely from oil, is an important additive for many rubber products. When added to tire rubber, it improves rubber's resistance to tearing, abrasion, and flex fatigue and also increases traction and durability. According to a recent study, "World Carbon Black," by industry consultant company Freedonia Group, a tire would last less than 5,000 miles without the addition of carbon black.

Freedonia, based in Cleveland, Ohio, estimates U.S. carbon black consumption at nearly 3.1 billion lb in 1993. Industry sources value that consumption at about $700 million. Worldwide, Freedonia estimates carbon black demand at 13.2 billion lb, equivalent to a global market of about $3 billion. Major worldwide carbon black producers include Cabot (Boston), Degussa Corp. (Ridgefield Park, N.J.), and Columbian Chemicals (Atlanta). In the U.S., at least three others are important producers: J. M. Huber (Edison, N.J.), Sid Richardson Carbon & Gasoline (Fort Worth), and Witco (Greenwich, Conn.).

Overall, carbon black consumption has tended downward in recent years, because smaller cars use smaller tires, and at least in the U.S., lower highway speed limits—55 mph—have prolonged wear. In addition, long-lasting radial tires have lengthened the time between tire replacements. But recent growth in the market for tire and industrial rubber may increase carbon black consumption in the future.

However, Freedonia's report cautions that tire makers are beginning to replace some carbon black with silica to improve tire rolling resistance and tire mileage rating and to decrease auto fuel consumption. But some manufacturers are prepared to face the challenge a real slowdown in carbon black consumption would pose. Carbon black manufacturers Huber, Cabot, and Degussa also can supply silica to tire makers.

Monsanto photo

Chemicals fortify under-the-hood hoses and belts.

According to Reinhard Stober, vice president and general manager for Degussa's carbon black division, weak demand for carbon black between 1989 and 1991 and then a price war among carbon black producers in 1992 and 1993 hurt carbon black producers' profitability. But demand for carbon black has improved along with the U.S. economy, and U.S. producers have been "sold out" since the beginning of this year, says Stober. Still, carbon black feedstock oil costs have risen, and recent increases in carbon black prices have only helped Degussa cover higher environmental costs. The company hopes to increase prices again this year. In any event, says Stober, the company has been caught between the fuel market and powerful buyers in the rubber tire industry, and so it has been "forced" to earn profits through improvements of process efficiencies.

Degussa's Stober thinks that tire (carbon) black consumption will grow at about 1.5% per year in the foreseeable future and not the 2 to 2.5% per year that industry consultants project. The slower growth is due to increased use of silica in rubber tires. But Degussa does not expect to lose out because of the increased use of silicas. According to Ken Cwick, vice president and general manager of Degussa's silica division, the company holds several patents covering the use of Degussa's proprietary silane in combination with the company's silica and carbon black to help tire manufacturers develop a product that achieves better rolling resistance while maintaining abrasion resistance and traction.

Cwick says that U.S. tires currently consume about 100 million lb of precipitated silica. Silica use will grow at a faster rate than overall tire rubber growth, because "everyone wants better fuel efficiency, longer tread life, and safer tires." Cwick says Degussa is prepared to aid the shift to improved tires.

Kyle Wendel, marketing director of Cabot's industrial rubber black business, agrees with Degussa's managers that, although demand and pricing for carbon black has improved in the U.S., the price increases have not been enough to counter higher production costs. However, he sees real growth and profit opportunities in supplying carbon black for industrial rubber products. Last month, Freedonia completed a report, "Industrial Rubber Products," which projects an annual growth of more than 6% for production of industrial rubber products in the U.S. between 1993 and 1998. Industrial rubber products include belts, hoses, elastomeric roofing, sheeting, and geomembranes for lining landfills or ponds.

New grades of carbon black will help improve industrial rubber's durability and performance at a competitive price, says Wendel. For instance, the company's carbon black product—tradenamed Sterling 1120—allows rubber to deliver good tensile strength at high loading in molded rubber products. The company's 6740 carbon black offers superior tear strength and surface appearance for extruded window channels and weather stripping.

Specialty carbon black for industrial rubber can enhance the high-temperature performance of an under-the-hood automotive hose, says Cabot applications development manager Steven Monthey. The company's carbon blacks can be especially effective in combination with high-temperature-resistant fluoroelastomers, because the addition of carbon black can lower the final cost of the fluoroelastomer part.

Many of the new carbon black grades are not simple "drop-ins" (replacements) for standard grades of carbon black, says Wendel. Customers will frequently have to reformulate their rubber compounds with the new specialty carbon blacks, he says, and the company's Norcross, Ga., applications development lab is ready to assist Cabot's customers in that effort.

Confident of the potential for specialty industrial-rubber-grade carbon blacks, Cabot currently has a new carbon black reactor line planned for its Sarnia, Ontario, facility, scheduled to operate in 1995. Carbon black is often considered a mature industry, but Cabot is trying to change that perception, says Wendel.

Antidegradants are largest class of rubber chemicals

U.S. consumption, millions of lb	1992	1993	1994[a]	1998[a]
Antidegradants	168.4	175.5	179.8	196.8
Accelerators	97.2	101.3	103.7	113.5
Miscellaneous	19.4	20.3	20.7	22.7
TOTAL	**285.0**	**297.1**	**304.2**	**333.0**

a Projections. **Source:** C&EN estimates

Tires account for most carbon black use

U.S. consumption, millions of lb	1993	1998[a]	2003[a]
Tire rubber	2,260	2,503	2,701
Nontire rubber	639	739	837
Other[b]	267	309	353
TOTAL	**3,166**	**3,551**	**3,891**

a Projections. b Includes uses in plastics, printing inks, and paints and coatings.
Source: Freedonia Group

Although carbon black and rubber chemicals are widely regarded as mature industries, that perception should not imply that new developments never happen in these areas. The use of silicas in longer lasting tires may change demand for carbon black, but industrial carbon blacks, such as those developed by Cabot, may help generate new markets for specialty carbon blacks. Rubber chemical producers also do not function within a vacuum and so have to respond to health and environmental concerns by coming up with alternatives to compounds that form potentially harmful airborne nitrosamines. And as rubber performance expectations change, particularly for automotive use, rubber chemical producers have to react by creating product variants that enhance rubber durability and heat resistance. ☐

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Companies find benefits, and barriers, in cooperative R&D with federal labs

Ann M. Thayer,
C&EN Northeast News Bureau

Facing cutbacks in research funding, chemical industry managers have found a new way to leverage resources through cooperative R&D agreements (CRADAs) with federal laboratories. These agreements are meant to spur the transfer of technology between federal labs and U.S. industry. Once a company has made a link with a federal lab, new opportunities and means for collaboration, contracting, or licensing often arise. But though deemed successful at the technical and technological levels, CRADAs have not been a panacea. And it is still too early in the program's life to know if the agreements will produce many tangible new products.

The number of CRADAs between industry and U.S. government labs has burgeoned. For example, CRADAs signed with Department of Energy labs since mid-1991 reached 974 by the end of July 1994. The total value of these DOE CRADAs is more than $1.9 billion. Another 466 CRADAs have been set up by the National Institute of Standards & Technology (NIST) since 1988, and the National Institutes of Health (NIH) has had 206 since 1986.

By the sheer numbers alone, it would seem that industry is finding the national labs accessible for R&D collaborations. And in general, companies are gaining access to federal labs, with just a few snags still remaining in the process. Chemical firms have been actively pursuing CRADAs, with several major companies, including Dow Chemical and DuPont, listed among DOE's top "repeat customers." Among other chemical producers involved with CRADAs are AlliedSignal, Olin, Rohm and Haas, W. R. Grace, and Union Carbide.

Clear government mandates directing technology transfer have caused CRADA activity, especially with the DOE labs, to pick up since 1990. And experience gained in negotiating CRADAs in the past few years has made the process go much more smoothly, say several government lab and chemical industry R&D and technology transfer managers interviewed by C&EN. Issues, they say, that centered on intellectual property, proprietary information, competitiveness, and bureaucratic delays have been better addressed.

"Getting CRADAs into place was a painful process at first," says Theodore Tabor, manager of cooperative research for Dow Chemical. "I believe it's gotten better [as] both the federal labs and industry have begun to learn how to work with one another." Dow currently has about 12 CRADAs with five national labs and with NIST in areas ranging from advanced materials to polymer processing to biosensors. Dow has another six agreements in various stages of negotiations, he adds.

The company's total investment in the agreements is about $5.9 million, or about 56% of the combined, cost-shared value of the CRADAs. Dow's contribution, like most industry cost sharing, is predominantly "work-in-kind," rather than actual cash, funding. Government labs can contribute personnel, equipment, facilities, and other resources but not funds.

"For a company Dow's size, I envision that interactions with the federal labs will continue to grow, not by leaps and bounds, but they will grow," says Tabor. "But I certainly don't envision this being a major push for the company. Dow has far more collaborations with universities than it does with federal labs." A factor, he says, is the longer association industry has had with academia compared with federal labs.

The level of familiarity and thus the ease of cooperation varies even among the different government organizations, notes Tom Patterson, external R&D manager for Dow's Texas and Louisiana sites. For example, he believes that the negotiation process is slower with DOE than it is with NIST, which has more years of experience working with industry.

According to NIST, its CRADAs take only about a month to implement, compared with several months or much more for other federal agencies. With industry and government having moved along the learning curve, government and industry technology transfer managers now believe that the negotiation process can be reduced to a few months.

"[A few years ago], the time frame was very long, and a DOE CRADA was very one-sided—very much for the government and not for industry," says Patterson. "Since then, there have been a number of different versions [of the agreement contract], and with each version there is improvement. The paperwork is becoming more palatable to industry, but it still is a very long document." As much as six months can pass while DOE, lab, and company attorneys agree on appropriate wording, he adds. But if the parties remain the same, negotiating a second CRADA can be done much faster.

New refrigerants developed through CRADAs are tested in industry facilities.

DuPont photo

Faith Silver, a DuPont patent associate focusing on the company's CRADA relationships, says that DOE has tried to use the experience it has gained in negotiating with companies, as well as delegating more authority to lab sites. DOE has created a "modular CRADA," in which alternative language can be substituted easily to suit given situations. "I think DOE has [tried] to understand industry's point of view in creating the modular CRADA," she says. "And DuPont has tried to set up contacts at the various labs . . . and a single voice within DuPont to speak for the needs of the company."

DuPont has 26 active CRADAs with different government orga-

Federal laws direct technology transfer

Legislation directing technology transfer by the government is more than a decade old. The Bayh-Dole Technology Transfer Act of 1980 set the stage by giving the government the right to own patents and by allowing nongovernment organizations to obtain patents or licenses on inventions developed with federal funding. Also in 1980, the Stevenson-Wydler Technology Innovation Act mandated that a small percentage of national laboratory funding be used for technology transfer.

Later, the Federal Transfer Technology Act of 1986 established the cooperative R&D agreement (CRADA) mechanism to promote the commercialization of federal technology from government-owned and -operated labs. By 1989, the National Competitiveness Technology Transfer Act firmly established technology transfer as a mission of all federal labs and facilities, including government labs operated by contractors. Continuing competitiveness initiatives, strategic plans, reorganization and redirection of lab roles, and other inducements by government departments and agencies have spurred technology transfer efforts by national labs.

Among the latest initiatives is Secretary of Energy Hazel R. O'Leary's April 1994 strategic plan (C&EN, April 25, page 34) directed at using Department of Energy's "tremendous scientific and technological assets . . . to help U.S. industry compete in a global economy." O'Leary's plan complements an earlier one that promoted "partnerships for global competitiveness" between DOE labs and U.S. industry (C&EN, Aug. 9, 1993, page 15). DOE is among the most active, having set up 974 CRADAs since mid-1991.

More than 80% of DOE CRADAs are at several major national laboratories—Sandia (191), Oak Ridge and its associated Y-12 plant (182), Lawrence Livermore (134), Los Alamos (111), Argonne (72), Pacific Northwest (55), and Lawrence Berkeley (51). Leading industry participants with 10 or more DOE CRADAs include GM (48), American Textile Partnership (30), California Institute for Energy Efficiency & Sponsors (22), IBM (18), United Technologies (16), Amoco (14), General Electric (12), DuPont (12), AT&T (11), and Hewlett Packard (10). Dow Chemical has nine.

nizations. The topics include the use of new or alternative refrigerants, supercomputing capabilities and computer modeling for chemical processes, high-temperature superconductors, and environmental treatment technologies. The company has another 27 CRADAs at various stages of discussion, says Randy Guschl, DuPont's director of corporate technology transfer, any six of which could become active by the end of this year.

DuPont is part of a $1 million CRADA signed in January with Monsanto, General Electric, and EPA to develop bioremediation technology to clean up hazardous waste sites (C&EN, Jan. 31, page 9). Each organization had been conducting work separately, says Philip Brodsky, Monsanto's director of corporate research and environmental technology, but the CRADA seemed to be a very good fit of complementary technologies, skills, and perspectives. The group recently received grant approval to demonstrate the technology at a DOE site.

"When EPA offered us a forum to propose collaborative research, we took advantage of that," he adds. "So far it has worked really well; we've actually helped each other advance the technologies." In addition, the CRADA has been called a new paradigm for EPA, in which it can act as a technical partner in solving environmental problems rather than just policing them.

The collaborative work also is facilitated because the technology being developed is viewed as noncompetitive and intended primarily for internal use. "All of the participants have remediation problems that they would like to deal with better, faster, cheaper," says Brodsky. "And it's really in everybody's best interest to come up with improved technology . . . and get these remediation problems behind us and get on with business.

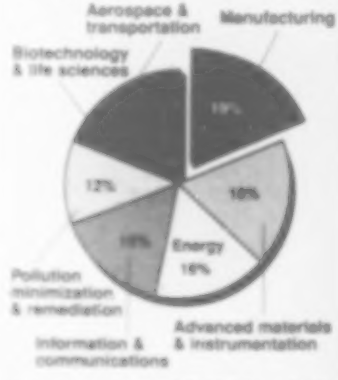
"In that sense maybe the CRADA is a little unique. If we were trying to join forces on technology which would be perceived as competitive, I think there would be many more issues," he continues. Some technology managers believe that CRADAs with consortia are more easily negotiated and the terms are more liberal because they avoid issues of unfair access to federal research and competitive advantages.

Technology transfer managers say that CRADA language relating to proprietary information and patent rights has become much more reasonable and balanced. Some go so far as to say that a CRADA is much more like a typical agreement with another company and that the overall negotiation process has become no more difficult than it is with universities or within industry. "At least the starting position [in CRADA negotiation] is balanced," comments one manager. "I think that is all one can ask for."

"If you see a major [intellectual property] issue, you can choose to do a part of the research where it won't be a problem," says Guschl. Under a CRADA, the government retains the right to use anything developed for its own purposes. "We don't have a problem with [that], it's fundamental in all government work and should be there," says Guschl, and other managers agree. "But in order to recover the investment of time and monies in developing a technology, we need to be able to develop and deploy that technology without a lot of others having direct access to it. So [the ability to get an exclusive license or patent] has become very important in negotiations."

But managers see a CRADA clause addressing U.S. competitiveness as a remaining issue. Specifically, many agreements require that products based on intellectual property developed under a CRADA be "substantially manufactured" in the U.S. In addition, any processes or improvements must be made in the U.S. at least simultaneously with, if not prior to, being made outside the

Manufacturing tops CRADAs at Department of Energy



Cumulative total of CRADAs = 974*

Note: Cooperative R&D agreements (CRADAs) classified by primary category; many fall into more than one category. * Mid-1991 through July 31, 1994.

A Lawrence Livermore National Lab scientist tests the insulation provided by silica aerogels, one of many high-tech materials studied under CRADAs.

U.S. while also not reducing the use of the technology in the U.S. DuPont chooses the technology for a CRADA carefully, says Silver. "We still have an interest in keeping DuPont a global business, and we feel that it is an economic concern for the United States to keep businesses such as DuPont healthy."

Defining the term "substantial" is left to the company, explains Patterson, and for an existing business, this can be done in terms of its current and projected operations. If the definition is accepted, it is incorporated in an addendum to the CRADA. But for new businesses, the manufacturing requirement can cause problems. "Frankly, some of the technology from the labs interests Dow for the longer term," Patterson says, "so we have accepted the clause without modification since market development and growth are not well-defined at this early stage."

At the same time, most industry technology transfer managers acknowledge the government's position and understand its desire to see transferred technology serve the interests of U.S. economic development.

A controversy relating to competitiveness has arisen with NIH CRADAs. NIH has been including language that gives it the right to specify prices for products developed under CRADAs. As a result, CRADAs with pharmaceutical and biotechnology companies have been hampered (C&EN, May 2, page 16). However, an NIH advisory panel recently has recommended that NIH drop the pricing policy.

Although technology transfer managers agree that the negotiation process has improved, they now say that industry faces a more serious problem. "Money is the biggest issue; everything else is secondary," says Patterson. "Industry first was frustrated by the paperwork taking too long, and now we're being frustrated by having the paperwork in order; having these huge labs, excellent facilities, and outstanding world-class researchers; having identified people we want to work with and who want to work with us; but unfortunately now [there isn't] the [federal] funding."

Opportunities simply to redirect funds seem slight, say managers, especially because the specific goals of a federal lab often do not overlap with those of a company. Adds Guschl: "A lot of the barriers have been worked out in the last few years, but we hear rumblings that CRADA funding might not continue as aggressively . . . and we are concerned about that, as we'd like to see the CRADA relationships continue.

"DuPont sees the need—partly because of the cost savings, partly because of the leveraging, partly because you can get to an answer quicker—to go to external technology sources and work with people whether [in] universities or government labs. We can envision in three to five years having as much as 5 to 10% of our R&D budget being deployed outside the company."

Many companies look to get involved in cooperative agreements, rather than in direct licensing of federal technology. "It's far more valuable to get involved with either a federal lab, or a university, on the ground floor of a research program and collaborate on specific work of interest to both parties," says Tabor of Dow, "and then have the opportunity to license technology if patents evolve." This approach also usually affords a company a more favorable position in negotiating patent rights and options for exclusive licenses, especially if funding was involved.

"If a lab truly had a technology available that was ready to license and it met the company's needs, we might indeed look at that. But as much as the federal labs around the country do have existing patents that they are trying to license through their technology-transfer offices, frankly we at Dow spend very little time looking at that existing patented technology. Same thing goes for university technology," says Tabor. "A lot of effort [gets] expended for very little return." ☐

Purified terephthalic acid capacity takes off

The market for purified terephthalic acid (PTA) is not a bad place for a chemical producer to be right now. Although the recession wreaked havoc on many chemical and plastic businesses, the PTA market seems to have emerged from the latest economic downturn largely unscathed. What's more, demand for PTA, which is a key raw material for production of polyester fibers and polyethylene terephthalate (PET) bottle resin and film, is expected to continue to grow roughly 8% per year at least until the end of the decade.

As a result, producers large and small have launched a bevy of expansion projects around the world. In the Asia-Pacific region, where most of the construction is concentrated, PTA capacity will rise by roughly 5 million metric tons between 1994 and 1998, representing a whopping 81% increase, according to Mary Belton Blackburn, director of polyester raw materials at Houston-based consultants Chemical Marketing Associates Inc. (CMAI). Major producers have been particularly aggressive, announcing expansion projects and conducting feasibility studies for more new plants even before they have completed construction of many others.

Producers say this latest capacity spurt is not due to any real unexpected jump in demand for PTA. Rather, capacity additions are needed to keep pace with demand, says Janice Florin, vice president for global business management for the chemical intermediates group at Chicago-based Amoco Chemical, which dominates the world market for PTA, with roughly 40% of worldwide capacity through wholly owned and joint-venture plants.

"It may seem that these expansions are happening all at once, but at Amoco at least, they are all part of a deliberate growth plan," says Florin. "Our expansion plans have been in the works for quite awhile, and a number of projects are just now coming to fruition. We have to be planning these expansions well in advance based on projected growth rates and taking into account that PTA plants take two to three years to build."

Expansions will boost global PTA capacity 62% by 1998

Thousands of metric tons	1994	1998	% change 1994–98
Asia-Pacific	6,510	11,775	81
North America	2,783	3,194	15
Western Europe	1,220	1,370	12%
Eastern Europe	0	330	—
South America	190	310	63
Africa & Middle East	70	420	500
TOTAL CAPACITY	**10,773**	**17,399**	**62%**

Source: Chemical Marketing Associates Inc.

London-based ICI, the world's second largest producer of PTA, agrees that the current onslaught of expansion activity is tied directly to "consistently strong growth in downstream polyester fiber and PET markets through the 1980s and now into the 1990s," according to a spokesman. But there's more to it than that. The current surge in activity has been sparked also by product shortages and high prices caused by underinvestment in new capacity between 1992 and 1994. Until recently, producers had been timid to provide funds to build new plants after having been burned by low prices and overcapacity in the 1989–91 period, says the ICI spokesman.

Despite the lessons learned in the past, ICI predicts that PTA producers will carry the current capacity boom too far, leading to another overcapacity problem by the late 1990s. "Some producers who are investing in sub-world-scale plants and old technology will find it very difficult to compete at this time," says the spokesman.

However, Amoco's Florin is hesitant to predict a future glut just yet. "It's too early to tell how supply will balance with demand in the late 1990s, because we don't know just how many of the announced expansion projects will actually bear fruit."

One limiting factor may be an impending shortage of *p*-xylene, the key feedstock for PTA production. Producers of *p*-xylene are not announcing expansion plans to keep pace with projected demand, especially in the Asia-Pacific region, notes CMAI's Blackburn, who will complete a study of world xylene and terephthalate markets through 2000 by the end of the year.

The "extremely healthy" state of the PTA market is a huge factor in gauging how supply and demand will balance out later in the decade, Florin says. Demand for polyester fiber is very strong in the Asia-Pacific region. And the PET container resin market has taken off over the past few years in North America, with current growth rates being pegged as high as 20% per year, she says.

Not surprisingly, North America may well be the center of the next round of PTA expansion announcements. In late June, Amoco announced plans to increase yearly PTA capacity by 115,000 metric tons at its Decatur, Ala., facility, with start-up scheduled for the second half of 1995. In addition, she says Amoco is "currently studying another North American expansion beyond the one at Decatur."

With its plants at Decatur and at Mt. Pleasant (Cooper River), S.C., Amoco is the only merchant producer of PTA in the U.S. However, ICI may disturb that position; the company is carrying out its own feasibility study for a U.S.-based PTA plant. The ICI spokesman could not give a date by which a decision will be made. In the U.S., ICI is a significant consumer of dimethyl terephthalate and will become a significant consumer of PTA when its new PET resin plant in Fayetteville, N.C., starts operating in the first quarter of 1996.

Meanwhile, ICI has announced expansions in Southeast Asia, the geographic region with the greatest demand for PTA. In early July, ICI confirmed that it had started engineering design work on a second PTA plant at its Kuan Yin site in Taiwan. The new 450,000-metric-ton-per-year plant is slated to operate in 1997. In addition, ICI plans to boost capacity at the existing two-year-old plant at Kuan Yin from 350,000 to 400,000 metric tons per year in 1995. "Continued growth in demand in Taiwan and the success of our existing purified terephthalic acid operation encouraged us to consider a further investment," says David Hewitt, ICI's international PTA business manager.

In addition, ICI plans to build a 400,000-metric-ton-per-year PTA plant at Port Qasim in Pakistan that will start operating in 1997. The investment will be made by ICI Pakistan, which is 61.5% owned by ICI; the remaining share is publicly traded in Pakistan. Deryk King, managing director of ICI's international polyester business, points out that PTA demand from the polyester fiber industry is now strong enough to justify building a plant in Pakistan, where ICI has been considering such an investment for some time. ICI expects that most of the plant output will be sold domestically, "but its leading cost economics will also enable the plant to compete aggressively in export markets."

Amoco is also extremely active in the Asia-Pacific region. The company's wholly owned facility in Kuantan, Malaysia, will add 500,000 metric tons per year of PTA capacity when commercial production begins in the second half of 1996. In addition, Amoco and the Japanese company Mitsui recently announced plans to build a jointly owned 350,000-metric-ton-per-year plant in Merak, West Java, Indonesia; construction has not yet begun but the plant is expected to begin operation in 1998, says Florin. Amoco's existing PTA joint ventures in Asia, China American Petrochemical Company Ltd. (CAPCO) and Samsung Petrochemical Company Ltd. (SPC), are also completing expansion projects due to start production in 1996, she says. CAPCO is building a 350,000-metric-ton unit in Taiwan; SPC's 250,000-metric-ton unit is in South Korea. In addition, Amoco has a project under way to build a 250,000-metric-ton-per-year PTA plant in Zhuhai, Guondong Province, China, says Florin.

Amoco is also keeping an eye on the European and South American PTA markets. In Europe, the company is evaluating capacity expansions, both in Geel, Belgium, where it now has a 250,000-metric-ton-per-year PTA unit, and in other locations.

In addition, this past March, Amoco do Brasil and Rhodia S.A., a subsidiary of France's Rhône-Poulenc, announced plans to evaluate the feasibility of modernizing and expanding their jointly owned PTA plant in Paulina, Brazil. Rhodiaco Industrias Quimica, a joint venture between the two companies, is considering boosting PTA capacity at its jointly owned facility from 110,000 to 230,000 metric tons per year. The feasibility study is expected to be completed sometime in October. Construction will begin by year's end and will be completed by late 1996.

Susan Ainsworth

Senate Approves Slight Increase To $80.9 Billion For 1995 Federal R&D

■ ***NIST appropriation would increase by half; gains by NSF, Defense, and NIH would be more modest in this budget***

Janice R. Long, C&EN Washington

The Senate has completed action on its versions of the fiscal 1995 appropriations bills. Overall, it has been more generous than the House in providing money for research funding agencies, allowing for a 1% rise over current funding levels to $80.9 billion. That's 2% more than the Administration had requested and 4% more than the House allowed (C&EN, July 11, page 25). Differences between the two branches' bills are now being settled by conference committees made up of members of the House and Senate Appropriations Committees.

Although it was able to provide an increase for this year, the Senate Appropriations Committee is concerned about the future of the federal R&D effort in the face of tight fiscal constraints. The National Science Foundation is a major beneficiary of this year's relative largesse and won praise from the Appropriations Committee for its efforts to address national needs.

NSF's total budget is slated to rise 14% to $3.5 billion, with funding for the research and related activities account also up 14% to $2.3 billion. Support for education and human resource programs would rise 186% to $606 million. The House provided for an overall increase of 12%, with research and related activities up 11%, and education and human resources up just 3%.

But the top gainer in the NSF budget itself was the academic research infrastructure account, which the Senate wants to increase by 186% to $300 million. However, not all of that money is intended for NSF, and most of it may never get spent. The Senate reserved $190 million for a new interagency academic research facilities and instrumentation modernization program. The funds would be available between Sept. 1, 1995, and Aug. 31, 1996. However, their release is contingent upon two criteria. First, the Administration has to submit to Congress on or before Sept. 1, 1995, a five-year strategy for the new initiative, which is to be run by NSF but cover all federal science mission agencies. Second, it has to request more funds for the initiative in fiscal 1996. If these two conditions are not met, the Senate Appropriations Committee says it likely will just rescind the money.

The Department of Defense also did quite well. The Senate provided a 5% increase to $37.8 billion for DOD's R&D programs, compared with the 2% cut to $35.1 billion slated for the same programs by the House. The House had directed DOD to cut $900 million in university research support out of its total fiscal 1995 R&D budget. The Senate, fearing that such a one-year decrease might disrupt legitimate defense-related research and cause undue hardship for the university community, decided to limit the cut to $82 million.

The Department of Commerce's National Institute of Standards & Technology fared just about equally well in both branches of Congress, with the Senate providing a 69% increase to $879 million, compared with the House's 62% increase to $842 million. Under NIST's Senate appropriations bill, funding for intramural chemical science and technology programs would rise 70% to $37.8 million, while funding for the Advanced Technology Program (ATP)—a shared-risk, industry-led program of joint R&D ventures designed to enhance U.S. competitiveness—would rise 121% to $441 million. That amount should enable NIST to provide an additional 200 ATP awards.

The National Institutes of Health is slated for a 4% rise to $11.3 billion under both the Senate and House appropriations bills. And both branches provided for a 3% increase to $902 million for the National Institute of General Medical Sciences, which provides the majority of NIH's chemical research funds.

Funding for the Department of Energy's energy R&D programs would fall 10% to $5.1 billion under its Senate appropriations bills, with funding for chemical sciences down 4% to $162 million and that for materials sciences down 1% to $274 million. The House, while cutting the overall energy R&D budget by the same percentage as the Senate, cut funding for chemical sciences 2% and froze funding for materials sciences. Funding for DOE's weapons R&D programs would fall 32% under both bills to $777 million.

Both the Senate and the House also allowed a 2% increase to $5.9 billion for the National Aeronautics & Space Administration's science, aeronautics, and technology programs. The Senate froze funding for the Department of Agriculture's research programs at $1.4 billion, while the House cut funding 4%.

Quite often, some of the most interesting information to come out in the annual appropriations process isn't contained in any of the 13 major funding bills, but rather it is in the written reports that accompany the bills to the House and Senate floors. Federal agencies tend to take that language very seriously indeed.

This year's Senate report on NSF's bill stands in sharp contrast to the one issued by the Appropriations Committee last year, which essentially told NSF that it had to start addressing, in a concrete way, the country's social and economic needs or see its money go to agencies that would do so. This year, there were nothing but kind words for NSF in the report that accompanied the VA, HUD, & Independent Agencies Appropriation bill.

The report praises the NSF director and the National Science Board for engaging

NIST, NSF get big boost in Senate-approved '95 R&D budget

$ Millions	1994	1995 Administration request	1995 Senate appropriation	% difference, appropriation-request	% change 1994–95
Defense	**$35,888**	**$35,962**	**$37,763**	**5%**	**5%**
Development	26,327	26,652	28,626	7	9
Operational systems	11,474	10,906	13,341	22	16
Engineering & manufacturing	7,441	8,916	8,850	–1	19
Advanced	4,669	3,846	3,621	–6	–22
Exploratory	2,743	2,984	2,814	–6	3
Management & support	3,218	3,079	2,959	–4	–8
Ballistic Missile Defense Organization	2,440	2,440	2,559	5	5
Demonstration & validation	2,698	2,566	2,497	–3	–7
Basic research	1,205	1,225	1,122	–8	–7
NASA	**15,113**	**14,284**	**14,035**	**–2**	**–7**
Science, aeronautics & technology	5,788	5,901	5,901	0	2
Human space flight	6,672	5,720	5,574	–3	–16
Mission support	2,653	2,663	2,560	–4	–4
Energy	**12,742**	**12,168**	**11,748**	**–3**	**–8**
Environmental restoration & waste management	5,899	5,961	5,858	–2	–1
Energy R&D	5,706	5,411	5,113	–6	–10
General science & research	1,615	1,110	974	–12	–40
Superconducting Super Collider termination costs[a]	640	180	0	na	na
Supporting research & technical analyses	976	956	949	–1	–3
Materials sciences[a]	277	274	274	0	–1
Chemical sciences[a]	169	162	162	0	–4
Waste R&D	687	703	703	0	2
Conservation	385	588	445	–24	16
Biological & environmental research	416	435	445	2	7
Fossil	431	451	436	–3	1
Solar & renewables	347	398	353	–11	2
Fusion	348	373	363	–3	4
Nuclear	341	248	308	24	–10
Environment, safety & health	160	149	137	–8	–14
Weapons R&D	1,137	796	777	–2	–32
NIH	**10,938**	**11,471**	**11,333**	**–1**	**4**
National Institutes	10,001	10,433	10,001	–4	0
General Medical Sciences[a]	876	908	902	–1	3
National Center for Research Resources	332	351	358	2	8
National Center for Human Genome Research	127	152	152	0	20
Other	478	535	496	–7	4
NSF	**3,018**	**3,199**	**3,454**	**8**	**14**
Research & related activities	1,993	2,348	2,265	–4	14
Education & human resources	570	586	606	3	6
Major research equipment	—[b]	70	150	114	na
Academic research infrastructure	105	55	300	445	186
Other	350	140	133	–5	–62
USDA	**1,416**	**1,347**	**1,416**	**5**	**0**
Agricultural Research Service	728	725	738	2	1
Cooperative State Research Service	495	419	480	15	–3
Forest research	193	203	198	–2	3
Commerce	**747**	**1,166**	**1,121**	**–4**	**50**
National Institute of Standards & Technology	520	935	879	–6	69
Oceanic & atmospheric research	227	231	242	5	7
TOTAL	**$79,962**	**$79,597**	**$80,870**	**2%**	**1%**

[a] Funds included in preceding total. [b] Data not available. **na** = Not applicable.
Source: Senate Appropriations Committee reports

"the scientific and engineering communities in a strategic planning process that recognizes the new realities and opportunities of the post-Cold War world order." It noted that NSF is improving its working relationships with other government agencies and industry and is putting in place formal mechanisms to reassess program priorities for the long term, set appropriate performance milestones and evaluation methods, and ensure accountability in the management and implementation of strategic research and education initiatives.

About the only things the committee was concerned about, as noted in the report, are that NSF draws only 5% of its expert reviewers from industry and that only 15% of its reviewers are new each year. The committee directed NSF to achieve an average of at least 10% industry reviewers within the next year and use a "significantly" higher percentage of new reviewers.

The Senate Appropriations Committee's overall assessment of the state of the federal R&D effort is not optimistic. In the NIH report, it notes that federal research agencies are being "confronted with constrained resources resulting from the virtual freeze in discretionary outlays." And it warns: "This freeze will make decisions over how to best allocate funding for R&D in the future all the more difficult as research opportunities collide with other governmental responsibilities required for preserving [and] protecting the health, safety, and economic security of our citizens."

These realities, the committee says, have compelled it to consider the composition of the overall federal R&D budget. It is particularly concerned whether that research budget is designed to meet new national security, military, economic, and health issues that confront the nation. To find out whether these concerns can be addressed at the present funding levels, the committee provided NIH with $1 million to commission a study from the National Academies of Sciences and Engineering and the Institute of Medicine. The study is to consider the criteria that should be used in judging the appropriate allocation of funds to research and development activities, the appropriate balance among the different types of institutions that conduct such research, and the means of ensuring continued objectivity in the allocation process. The study is due Dec. 31, 1995. ☐

EPA tries to pare number of toxics release forms

The Environmental Protection Agency would like to cut down on the number of Toxics Release Inventory (TRI) forms it has to process each year. So the agency has proposed exempting facilities that transfer or release less than 100 lb per year of a listed chemical from TRI reporting requirements. EPA estimates this exemption would save industry $26 million in costs and result in 20,500 fewer TRI reports filed with EPA.

The proposed regulation comes in response to petitions filed with EPA in 1991 and 1992 by the Small Business Administration (SBA) and the American Feed Industry Association (AFIA). The two groups maintain that many very small facilities incur too much expense trying to comply with the current regulation. "The TRI database is not meaningfully improved by countless entries of zero or de minimis release figures," states the SBA petition.

AFIA asked that its entire industry be exempted from the reporting requirement because its companies release such small amounts of chemicals into the environment that the information does not contribute anything significant to the TRI database. In fact, Brian L. Bursiek, director of feed production at AFIA, claims that a 100-lb exemption would eliminate 50 to 60% of the TRI forms that now have to be filed. Most of the substances released by AFIA facilities result from the addition of nutrients such as manganese, zinc, and copper sulfate to processed feed.

In view of this, EPA has looked at the TRI data to see if some of the information collected may be of lesser value than some of the new reports expected to result from EPA's current efforts to expand TRI. Because of the large number of forms it found reporting zero-release amounts, the agency decided to see if a low-release exemption would work.

EPA says it received 10,200 reports on 1991 TRI release forms that recorded zero releases or transfers. "EPA believes that the space that such reports consume in the database and the effort necessary to submit the reports would be better applied to those additional reports that contain positive values for releases and transfers of toxic chemicals," the agency states in the proposed regulation.

Although EPA has removed some chemicals from the TRI reporting list, the proposed exemption would be the first major regulation issued by EPA cutting back release reporting. TRI was created in the 1986 Superfund reauthorization bill and has subsequently become one of the agency's primary information sources. The law requires any manufacturing facility that handles more than 25,000 lb per year of a listed chemical to report to EPA any releases of the chemical into the environment, or any transfers or treatments of those chemicals. The inventory list contains more than 300 chemicals and 20 chemical categories. For 1992, the latest year's data, EPA received more than 81,000 reports from companies.

Exempting small volumes cuts down on TRI reports

Threshold level (lb)	No. of reports affected (thousands)	Volume of waste unreported (lb)	% of total waste reported
0	10.2	0	0.00%
10	16.2	35,000	0.00
100	20.5	200,000	0.01
250	26.2	1,400,000	0.03
500	33.0	4,000,000	0.1
1,000	38.9	8,400,000	0.2
5,000	50.1	36,200,000	0.8

Note: Data are from 1991 Toxics Release Inventory reports of releases of specified toxic chemicals and of transfers of them for the purpose of treatment and disposal. **Source:** Environmental Protection Agency

And the agency is in the process of a major expansion of the scope of TRI. In January, EPA proposed adding 313 substances to the list of reportable chemicals and requiring facilities outside the manufacturing sector to report releases. Those changes are expected to increase the number of reports by about 28,000 annually, EPA estimates. An exemption for very minor releases could probably significantly lower that number.

However, companies that release less than 100 lb of a listed chemical will not get away from EPA paperwork entirely. To qualify for the exemption, a company would have to file an annual certification statement in lieu of the full form inventory report. A company would have to include much of the same data included on the TRI form, but indicate that the substance released falls into a range of 0 to 99 lb and qualifies for the exemption.

Bursiek of AFIA thinks such annual reporting is unnecessary. "We contend that once you have claimed an exemption, you should not have to do that every year," he says. Filing the similar paperwork each year seems to negate the advantage of the exemption, he believes.

But the agency says that annual certification is in keeping with the statutory requirement of the law and will provide data on the manufacture and processing of the listed chemicals. It will also "foster continued attention to chemical management practices and provide a location tool vital to any compliance program," the proposed regulation states.

EPA estimates if the exemption becomes final at 100 lb, about 15 chemicals will no longer be reported at all on the inventory. These chemicals were only reported on 26 forms in 1991. The greatest volume among them was for 2,4-diaminoanisole, which one company reported releasing a total of 85 lb that year. The total amount released for all 15 chemicals was less than 320 lb.

While some industries, such as AFIA, would gain some advantage from this kind of exemption, the chemical industry sees little that will help it. Nancy Lawson of the Chemical Industry Council of New Jersey says that an exemption level of 100 lb is just too little. "EPA is kind of throwing us a bone," she says. A larger volume exemption, say of 500 lb, would be more appropriate for chemical firms, she adds.

Cheryl O. Morton, manager of government relations at the Washington, D.C.-based Synthetic Organic Chemical Manufacturers Association, which represents many smaller chemical companies, says that the industry is at best lukewarm to the EPA proposal. The original SBA petition was for a 5,000-lb exemption, Morton says, and that is what would provide the relief from TRI reporting that the industry needs. She agrees with Lawson that few chemical facilities would be expected to benefit from a 100-lb reporting exemption.

Environmental activists are wary of EPA efforts that might result in less information being made available to the public about hazardous chemicals. A spokesperson for the Environmental Defense Fund, for example, says a threshold exemption would be a step backwards if it did not include all material sent for recycling and not just material released. Even then, a threshold of 100 lb might still be unacceptably high.

David Hanson

Second And Third Groups Of ACS-PRF Grants Approved

Acting on recommendations from the February and May meetings of the Petroleum Research Fund Advisory Board, the ACS Board of Directors approved 251 new or continuing ACS-PRF grants-in-aid with a total value of $7,814,252. The recommended grants were selected from 833 proposals and are the last projects to be funded in 1994. ACS-PRF grants are funded by income from a trust established in 1944 by seven major oil companies. No ACS member dues income is used for PRF grants or administrative expenses.

Continuing low interest rates have reduced income available for new PRF grant commitments. New PRF grants declined from $14.4 million in 1992 and $12.9 million in 1993 to $12.3 million in 1994. A further decrease in commitments in 1995 is probable. The 1994 success rates are 23% for Type AC grants, 44% for Type B grants, and 36% for Type G "Starter" grants.

In order to hold the projected 1995 success rate for Type AC proposals above 20%, the supplements for Summer Research Fellowships for faculty from undergraduate departments will be suspended in 1995 and 1996. Further, applicants for a Type AC grant which is not funded may not have another AC proposal considered until 12 months later.

The "38th Annual Report on Research Under Sponsorship of The Petroleum Research Fund" is now available. Individuals who wish a complimentary copy, or information and application forms for ACS-PRF grants to commence in 1995, should write the Petroleum Research Fund, American Chemical Society, 1155—16th Street, N.W., Washington, D. C. 20036; phone (202) 872-4481.

ACS-PRF Grants for Fundamental Research in the Petroleum Field (Type AC)

John B. Anderson, Rice U. Architecture of Late Pleistocene to Holocene Incised Valley-Fills on the Texas Shelf. $50,000

James K. Bashkin, Washington U. Functional Mimics of Ribozymes: Catalytic DNA. $50,000

Peter F. Bernath, U of Waterloo. Laser and Fourier-Transform Spectroscopy of Free Radicals. $50,000

Kit H. Bowen Jr., Johns Hopkins U. Magic Clusters: Their Formation and Characterization in Beams and the Bulk. $50,000

Udo H. Brinker, State U of New York, Binghamton. Carbenes in Constrained Systems. $50,000

Philip R. Brooks, Rice U. How Does Molecular Orientation Affect Electron Transfer? $50,000

Kenneth L. Brown, Mississippi State U. Diastereomerism in Organocobalt Corrinoids. $50,000

Douglas W. Burbank, U of Southern California. Style and Rate of Detachment Folding and Impacts on Coeval Depositional Systems. $50,000

Theodore J. Burkey, U of Memphis. Hydrogen Activation by Transition-Metal Complexes. $50,000

William D. Carlson, U of Texas, Austin. Compositional Dependence of Apatite Fission-Track Annealing: An Experimental Approach. $50,000

Barry K. Carpenter, Cornell U. Elucidation of the Relationship Between Biradicals and Zwitterions in Organic Thermal Reactions. $50,000

Arup K. Chakraborty, U of California, Berkeley. Structure of the Interface Between Metals and Random Copolymers: Taking Steps Toward the Molecular Design of Adhesives. $50,000

Daniel L. Comins, North Carolina State U. Photocycloadditions of Dihydropyridones. $50,000

Philip Coppens, State U of New York, Buffalo. Diffraction Studies of Excited State Structure. $50,000

James A. Cowan, Ohio State U. Mechanistic Studies of Metallonuclease Enzymes. $50,000

James V. Crivello, Rensselaer Polytechnic Inst. Synthesis and Polymerization of Novel Ketene Acetal Monomers. $50,000

M. David Curtis, U of Michigan. Self-Assembling Conjugated Polymers. $50,000

Robert J. Davis, U of Virginia. Selective Oxidation of Hydrocarbons Over Titania-Silica Mixed Oxide Catalysts. $50,000

John M. Dealy, McGill U. Dynamic Wall Slip of Molten Polymers. $50,000

David Deming, U of Oklahoma. Overpressures, Temperature, and Hydrocarbon Generation in the Anadarko Basin. $50,000

Michael F. Doherty, U of Massachusetts. Design of Melt Crystallization Processes by Equation-Based Methods. $50,000

James H. Edgar, Kansas State U. Chemical Vapor Deposition of Diamond-Cubic Boron Nitride Alloys. $50,000

Mark D. Ediger, U of Wisconsin, Madison. Translational Diffusion of Probes in Polymers Near T_g. $50,000

R. Lawrence Edwards, U of Minnesota, Minneapolis. Mass Spectrometric ^{231}Pa/^{235}U Dating of Carbonates: Testing High Resolution Records of Quaternary Climate Change. $50,000

Arthur B. Ellis, U of Wisconsin, Madison. Chemical Sensors Based on the Photoluminescence of Metal-Complex-Coated Semiconductors. $50,000

John L. Falconer, U of Colorado. Catalytic Oxidation Mechanisms of Volatile Organic Compounds. $50,000

Gerald W. Feigenson, Cornell U. Monte Carlo Simulation of Nonideal Mixing in Model Membranes. $50,000

Robert W. Field, Massachusetts Inst. of Technology. Fundamental Mechanisms of Energy Exchange Between an Electron and a Molecular Cation. $50,000

Randy S. Fishman, North Dakota State U. Simulations of Void Formation in Organic Coatings and Other Composite Media. $50,000

Eric L. Garfunkel, Rutgers, State U of New Jersey. Initial Oxidation of Nickel and Silicon: From a Phenomenological Description to an Atomic-Scale Understanding. $50,000

Robert E. Garrison, U of California, Santa Cruz. Sequence Stratigraphic Modeling and Recognition of Sea-Level Changes in a Proximal Monterey Setting: Cuyama Basin of California. $49,961

George R. Gavalas, California Inst. of Technology. Membrane Preparation via Supported Carbon Layers. $50,000

William E. Geiger Jr., U of Vermont. Redox Properties of Unusual Polynuclear Complexes. $49,940

Gregory I. Gellene, Texas Tech U. Nuclear Symmetry Restrictions in Chemical Reactions. $50,000

Edwin S. Gould, Kent State U. Hypovalent Metal Centers from Intramolecular Hydride Transfers. $25,000

Martin Gruebele, U of Illinois, Urbana-Champaign. Rapid Protein Folding Dynamics. $49,933

Carol K. Hall, North Carolina State U. Theories for Fluids Containing Chain-Like Molecules. $50,000

Gary L. Haller, Yale U. A Comparison of Amorphous and Mesoporous Molecular Sieve Silica-Aluminas. $50,000

William W. Hay, U of Colorado. Role of Large Amplitude Sea-Level Changes on the Late Neogene-Quaternary Increase in Sediment Delivery to the Deep Sea. $50,000

Harold C. Helgeson, U of California, Berkeley. Thermodynamic Constraints on the Chemical Evolution of Kerogen in Sedimentary Basins. $50,000

Victor E. Henrich, Yale U. Effect of Substrate Electronic Structure on the Chemisorption Properties of Cr-Doped V_2O_3. $50,000

James W. Herndon, U of Maryland, College Park. Development of New Annelation Reactions Using Z-Vinylacetylenes and Fischer-Carbene Complexes. $50,000

Davide A. Hill, U of Notre Dame. Relaxation of Monolayers of Dielectrically Responsive Polymers Tethered to Solid Surfaces. $50,000

Michael F. Hochella Jr., Virginia Polytechnic Inst. & State U. Fundamental Processes at Mineral Surfaces: A Study Using Ambient and UHV-Based Scanning Probe Microscopies and Spectroscopies. $50,000

George M. Homsy, Stanford U. Flow, Transport, and Instabilities in Strongly Heterogeneous Porous Media. $40,000

Martin F. Jarrold, Northwestern U. Structural Dynamics of Pure and Doped Carbon Cluster Ions. $50,000

Graham B. Jones, Clemson U. Catalytic Asymmetric Induction Based on J Stacking Interactions. $50,000

Stephen E. Kesler, U of Michigan. Geochemistry and Significance of Methane in Mississippi Valley-Type Deposits. $50,000

Saad A. Khan, North Carolina State U. Rheology of UV Cross-Linked Polymers. $50,000

David A. Kofke, State U of New York, at Buffalo. Some New Ideas for the Treatment of Conformal Solutions. $50,000

Paul J. Kropp, U of North Carolina, Chapel Hill. Surface-Mediated Reactions. $50,000

Stephen G. Kukolich, U of Arizona. Microwave Measurements of the Structures of Transition-Metal Complexes. $50,000

Richard C. Larock, Iowa State U. Palladium-Catalyzed Annulation. $50,000

Mario Leclerc, U of Montreal. Synthesis and Characterization of Novel Electroactive and Photoactive Polyesters. $50,000

Doreen G. Leopold, U of Minnesota, Minneapolis. Studies of Transition-Metal-CO Bonding by Negative Ion Photoelectron Spectroscopy. $50,000

Frederick D. Lewis, Northwestern U. Photoswitchable Hydrogen Bonds. $50,000

Mark A. Lipton, Purdue U. Enantioselective Synthesis of Monosaccharides and Their Derivatives. $50,000

Carl R.F. Lund, State U of New York, Buffalo. Microkinetics of Water-Gas Shift Over Pd, Pt, and Rh. $50,000

Przemyslaw B. Maslak, Pennsylvania State U. Spiroconjugated Charge-Transfer Dyes. $50,000

James R. Maxwell, U of Bristol. 1-H-Pyrrole-2,5-Diones as Indicators of Redox Conditions in Ancient Water Bodies. $43,380

Anne M. Mayes, Massachusetts Inst. of Technology. Phase Diagram of Compressible Block Copolymer Melts. $25,000

Andreas Mayr, State U of New York, Stony Brook. Coordination Chemistry of Multiply Unsaturated Organic Ligands. $50,000

David A. McConnell, U of Akron. Study of Outcrop-Scale Structures in the Valley and Ridge Province, Appalachian Orogen: Implications for Fault-Fold Interactions. $18,950

Michael J. McGlinchey, McMaster U. Organometallic Cations and Anions. $50,000

Peter S. Mozley, Andrew R. Campbell, New Mexico Inst. of Mining and Technology. Petrographic and Geochemical Correlation of Carbonate-Cemented Horizons in Siliciclastic Rocks. $50,000

Sohail Murad, U of Illinois, Chicago. Computer Simulation Studies of Osmosis and Reverse Osmosis in Solutions. $50,000

E. Bruce Nauman, Rensselaer Polytechnic Inst. Self-Assembled Structures Resulting from Multicomponent Spinodal Decomposition. $50,000

John S. Oldow, Rice U. Low-Angle Displacement Transfer System in the Walker Lane Strike-Slip Belt, West-Central Nevada. $50,000

Athanassios Z. Panagiotopoulos, Cornell U. Monte Carlo Simulations of Phase Coexistence for Lattice Polymeric Models. $50,000

Robert L. Powell, U of California, Davis. Fluid Mechanics and Rheology of Suspensions of Bimodally Distributed Spherical Particles. $50,000

Philip P. Power, U of California, Davis. Synthesis and Structure of Magnesium Imide Cage Compounds and Their Applications as Synthetic Reagents. $50,000

Daniel E. Resasco, U of Oklahoma. Modification of the Role of Hydrogen in Alkane Dehydrogenation Catalysts by the Addition of Metal Promoters. $50,000

J. Donald Rimstidt, Virginia Polytechnic Inst. & State U. Clay Mineral Precursors Formed During Silicate Mineral Weathering. $50,000

Mark O. Robbins, Johns Hopkins U. Dissipative Mechanisms in Friction and Adhesion. $50,000

Gregory H. Robinson, Clemson U. Host-Guest Complexes as Templates for the Molecular Assembly of Novel Alanes Containing Al-Al Bonds. $50,000

Matthew J. Rosseinsky, U of Oxford. Synthesis of New Transition Metal Oxides. $50,000

James P. Runt, Pennsylvania State U. Interphases in Semi-Crystalline Polymer Blends. $50,000

Douglas M. Ruthven, U of New Brunswick. Zeolitic Diffusion in a Binary Adsorbed Phase. $50,000

Cyrus R. Safinya, U of California, Santa Barbara. Biomolecular Membranes Based on Lipids, Membrane-Associated Proteins, and Surfactant Polymers. $50,000

Michael Savarese, Indiana U. Paleobiological and Paleoenvironmental Context of Coralomorph-Bearing Lower Cambrian Reefs, South Australia: Implications for Paleozoic Reef Ecology. $49,981

Cynthia K. Schauer, U of North Carolina, Chapel Hill. Multielectron Redox Reactions of Transition-Metal Clusters: Origins and Chemical Implications. $50,000

Juergen Schieber, U of Texas, Arlington. Exploring the Origin of Large-Scale Erosion Surfaces in the Chattanooga Shale: Testament of Mud-Bank Migration? $50,000

Gary J. Schrobilgen, McMaster U. New Fluorides and Oxofluorides of Xenon(VIII). $50,000

Gustavo E. Scuseria, Rice U. Theoretical Studies of Fullerene Annealing and Fragmentation. $50,000

Scott McN. Sieburth, State U of New York, Stony Brook. Intramolecular Toolbox: Multipurpose Organosilanes. $50,000

Jay S. Siegel, U of California, San Diego. Investigation of Transition-Metal Tripods and Trinuclear Metal Clusters with Arenes: Theoretical and Experimental Models for Metal Catalysis. $50,000

Bernd R.T. Simoneit, Oregon State U. Characterization of Organometallic Complexes in Hydrothermal Petroleum. $50,000

Jennifer L. Sinclair, Carnegie Mellon U. Quantitative Prediction of Heat Transfer Rates in High Velocity Fluidization. $50,000

James L. Skinner, U of Wisconsin, Madison. Spectral Diffusion of Individual Molecules in Solids. $50,000

Mark A. Smith, U of Arizona. Temperature Dependent Free-Radical Kinetics Between 20 and 300 K. $50,000

Stuart W. Staley, Carnegie Mellon U. Effect of Molecular and Crystal Structure on Dynamic Processes in the Organic Solid State. $50,000

Howard A. Stone, Harvard U. Dynamics of Deformable Drops and Bubbles in Suspensions. $50,000

Donald C. Sundberg, U of New Hampshire. Polymer End Groups at Aqueous and Organic Interfaces: Influence on Latex Particle Morphology. $50,000

Daniel R. Talham, U of Florida. New Conducting and Superconducting Cation Radical Salts Based on High-Oxidation State Organic Donors. $50,000

Boon K. Teo, U of Illinois, Chicago. Single-Crystal X-Ray Diffraction and EXAFS Studies of Biand Trimetallic Clusters in Zeolite Cages. $50,000

Frantisek Turecek, U of Washington. Hydrochlorofluorocarbon Radicals. $50,000

Veronica Vaida, U of Colorado. Photoreactivity of Complexes via Time Resolved UV Fourier-Transform Spectroscopy. $50,000

Philippe Van Cappelen, Georgia Inst. of Technology. Controls on the Degradation and Preservation of Organic Carbon, Nitrogen, and Phosphorus in Marine Sediments. $50,000

John G. Verkade, Iowa State U. Atranes as Probes for Novel Chemistry and Structures. $50,000

Paul Weimer, U of Colorado. An Integrated Four-Dimensional Structural Analysis of Allochthonous Salt Sheets, Northern Gulf of Mexico. $38,957

W. Henry Weinberg, U of California, Santa Barbara. Bridging the Pressure Gap in Heterogeneous Catalysis: Use of Atomic Beams in Catalytic Hydrogenation Reactions. $50,000

James C. Weisshaar, U of Wisconsin, Madison. Gas-Phase Reactions of Neutral Transition-Metal Atoms with Alkanes and Alkenes. $50,000

Mark E. Welker, Wake Forest U. Synthesis and Reaction Chemistry of Unusual Transition-Metal η^1-1,3-dienyl, η^1-1,2-dienyl, and η^3-cyclobutenone Complexes. $50,000

William Weltner Jr., U of Florida. Magnetic–Optical Studies of Small Clusters. $50,000

Kenton H. Whitmire, Rice U. Bismuth Oxo Cluster Compounds and Oxidation Catalysis. $50,000

John M. Wiest, Purdue U. Inception of Homogeneous Failure in Amorphous Solids: A Molecular Dynamics Study. $50,000

Robert M. Williams, Colorado State U. Synthesis and Biosynthesis of the Brevianamides/Paraherquamides. $50,000

L. Keith Woo, Iowa State U. New Group 14, 15, and 16 Transfer Reactions: Scope, Kinetics, and Mechanisms. $50,000

Sidney Yip, Massachusetts Inst. of Technology. Instabilities of Solids Under Stress. $50,000

Tadeusz W. Zerda, Texas Christian U. Diffusion in Small Pores and Gradient Index Sol-Gel Glass. $50,000

John Z. H. Zhang, New York U. Time-Dependent Approach to Diatom-Diatom Reactions. $50,000

ACS-PRF Grants for Fundamental Research in the Petroleum Field (Type B)

Alaa S. Abd-El-Aziz, U of Winnipeg. Controlled Design of Oligomeric and Polymeric Arene Complexes. $25,000

Edward R. Biehl, Southern Methodist U. Preparation of Functionalized Polycyclic Arenes Using Arynic Methodology. $25,000

Walter J. Bowyer, Hobart & William Smith C. Rates and Mechanism of Grignard Reagent Formation by in situ Photomicrography of Magnesium Surfaces. $25,000

Thomas M. Christensen, U of Colorado, Colorado Springs. Exploring Interfaces: Three-Dimensional, Non-Destructive Characterization of Multilayer Film Systems. $25,000

Susan T. Collins, California State U, Northridge. Matrix-Isolation Studies of Excited-State Proton-Transfer Systems. $25,000

Roger L. DeKock, Calvin C. Theoretical Challenges in Transition-Metal Clusters That Include Main-Group Atoms. $25,000

Thomas C. DeVore, James Madison U. Rapid Scan FTIR Investigation of Metal Complex/Small-Molecule High-Temperature Chemical Reactions. $25,000

Gregory W. Ebert, State U of New York, Buffalo. Direct Formation of Halovinylcopper Reagents and the Carboxylation of Functionalized Arylcopper Compounds. $25,000

Luther E. Erickson, Grinnell C. Structural, Equilibrium, and Kinetic Studies of Platinum Complexes. $25,000

Karen I. Goldberg, Illinois State U. Reactivity Trends in Reductive Elimination Reactions. $25,000

John T. Gupton, U of Central Florida. Use of Vinylogous Iminium Salt Derivatives for the Regiocontrolled Synthesis of Trisubstituted Pyrroles: A Pyrrole Based Approach to Rigidin. $25,000

Michael A. Kahlow, U of Wisconsin, River Falls. Chemistry of Chlorin d Substituted Myoglobin. $25,000

Frederick W. King, U of Wisconsin, Eau Claire. Investigation of the Rydberg States of the Lithium Atom. $25,000

Timothy D. Lash, Illinois State U. Synthesis and Characterization of Novel Conjugated Macrocycles Related to the Oxophlorins. $25,000

Joon C. Lee, U of Southern Mississippi. Binary Liquids in Porous Media. $25,000

John A. Maguire, Southern Methodist U. Structural and Spectral Properties of Main Group J Complexes. $25,000

Harmon D. Maher Jr., U of Nebraska, Omaha. Kinematic Evolution of Tertiary Structures in a Dextral Transpressional Plate Setting, Western Barents Shelf, Spitsbergen, Norway. $19,700

Nancy S. Mills, Trinity U. Dications of Bifluorenylidene: Factors That Affect Reactivity and Reactions in Phenyl-Substituted Polycations. $25,000

Ronald L. Musselman, Franklin & Marshall C. Polarized Specular Reflectance of Binuclear Metalloprotein Models and Planar One-Dimensional Conductors and Precursors. $25,000

Paul M. Myrow, Colorado C. Cambrian Tidal Sand Waves: Geometry, Sediment Dynamics, and Reservoir Potential. $24,450

Allan M. Nishimura, Westmont C. Triplet-Triplet Energy Transfer of Adsorbed Organic Species. $25,000

Craig A. Ogle, U of North Carolina, Charlotte. Chiral Resolution of Racemic Alkyllithium Reagents. $25,000

John A. Olmsted III, California State U, Fullerton. Studies of Energy and Charge Transfer in Transparent Sol-Gels. $25,000

James H. Reynolds, Western Carolina U. Magnetic Polarity Stratigraphy of Continental Strata in the Sierras Subandinas, Northwest Basin, Salta Province, Argentina. $25,000

Rabindra N. Roy, Drury C. Thermodynamic Study of Electrolyte Mixtures. $25,000

Carl Salter, Moravian C. Ab initio Investigation of the N_3H_3 Surface and Triaziridine-Polycyclic Ring Systems. $24,000

Michael R. Sandy, U of Dayton. Early Mesozoic Brachiopod Faunas from North America: Paleoenvironmental, Paleogeographic and Stratigraphic Significance, and Role in the Development of the Modern Brachiopod Fauna. $25,000

Lauret E. Savoy, Mount Holyoke C. Provenance Analysis of a Middle Paleozoic Marine Sequence, Southern Canadian Rocky Mountains: Link Between Tectonics and Sedimentation. $25,000

Charles D. Schaeffer Jr., Elizabethtown C. Structure and Reactivity of Incipiently Hypervalent Compounds of Silicon and Tin. $25,000

Karen A. Singmaster-Hernandez, San Jose State U. Bis(trifluoromethyl)oxirene. $25,000

Joanne A. Smieja, Gonzaga U. Synthesis of Organoimido Metalloporphyrin Complexes: Possible Alkene Aziridination Reagents. $25,000

James N. Spencer, Claude H. Yoder, Franklin and Marshall C. A Comparative Study of Host-Guest Interactions in Aqueous and Nonaqueous Media. $25,000

E. Timothy Wallin, U of Nevada, Las Vegas. Test of a Parautochthonous Sonomia. $25,000

Thomas C. Werner, Union C. Fluorescence Probe Studies on Cyclodextrin Polymers. $25,000

Karl R. Wirth, Macalester C. Origin and Evolution of Intra-Arc Basins Along the Philippine Strike-Slip Plate Margin. $25,000

Patty Wisian-Neilson, Southern Methodist U. Reactions of Low-Coordinate Phosphorus Compounds with New Phosphido-Bridged Diiron Anions. $25,000

Phillip A. Zoretic, East Carolina U. A Radical Approach to Diterpenes. $25,000

ACS-PRF Grants for Fundamental Research in the Petroleum Field (Type G)

Awarded to faculty in Ph.D.-granting departments

Maria A. Barrufet, Texas Engineering Experiment Station. Determination of Partition Coefficients, Density and Viscosities of Brines/CO_2/Hydrocarbon Systems Using NMR. $20,000

Kay M. Brummond, West Virginia U. A Novel Intramolecular 1,3-Dipolar Cycloaddition Using a Sulfine and Its Application to the Synthesis of Antitumor Antibiotic Sarkomycin. $20,000

Vincent J. Catalano, U of Nevada, Reno. Square Planar d^8 Transition-Metal Complexes and Their Application in Stabilized Multiple Metal-Metal Bonded, Donor-Acceptor Complexes. $20,000

William E. Crowe, Emory U. Catalytic Allene Activation by Transition Metal "Heteroatoms". $20,000

Stephen G. DiMagno, U of Nebraska, Lincoln. New Mixed Valence Materials. $20,000

Ulrike Diebold, Tulane U. Study of Metal Nanoclusters on Surfaces of Metal-Oxide Thin Films. $20,000

Mark D. Distefano, U of Minnesota, Minneapolis. Design of Regioselective Reaction Catalysts Based on Fatty Acid Binding Protein. $20,000

Julie L. d'Itri, U of Pittsburgh. Utilization of Waste Emission Streams from Stationary Power Sources for the Production of Fuels and Chemicals. $20,000

Felicia A. Etzkorn, U of Virginia. Conformationally Constrained Mimics of Helix-Loop-Helix DNA-Binding Proteins. $20,000

Christine E. Evans, U of Michigan. Fundamental Studies of Interfacial Interactions. $20,000

Brian G. Fox, U of Wisconsin, Madison. Definition of the Reactivity of Toluene-4-Monooxygenase: A New Type of Iron-Oxo Enzyme that Hydroxylates Alkanes, Alkenes, Aromatics, and Halogenated Hydrocarbons. $20,000

Steven H. Frankel, Purdue U. A Computational Investigation of Turbulent Nonpremixed Flame Dynamics. $20,000

James A. Glazier, U of Notre Dame. Evolution and Rheology of Three-Dimensional Foams. $20,000

Clare P. Grey, State U of New York, Stony Brook. Study of Acid Catalysts Using Double and Triple Resonance Solid-State NMR Spectroscopy. $20,000

Michael M. Haley, U of Oregon. Cyclophynes: A New Class of Highly Unsaturated Hydrocarbons. $20,000

Richard C. Holz, Utah State U. NMR Spectroscopy as a Probe of Dicopper(II) Centers. $20,000

Michael D. Johnson, New Mexico State U. Exploration of the Fundamental Chemistry of the Ferrate Ion FeO_4^{2-}. $20,000

Stephen E. Johnson, U of Iowa. Synthetic Approaches to Molecular Networks Comprising Main Group Elements and Alkyne Units. $20,000

Wayne E. Jones Jr., State U of New York, Binghamton. Electrochemical Investigations of Transition-Metal Radicals by Phase Modulated Voltammetry (PMV). $20,000

Zhao Kang, New York U. Stabilization of Sulfonium Ions for Diastereoselective Glycosylation and Potential Application to Solid Phase Chemistry. $20,000

Piotr Kaszynski, Vanderbilt U. Dative Bonds in Liquid Crystals. $20,000

Bruce J. Kellett, U of Cincinnati. Microstructures of Minimum Interfacial Energy. $20,000

Paul E. Laibinis, Massachusetts Inst. of Technology. Use of Covalently Incorporated Silsesquioxanes in Polymeric Networks. $20,000

Gustavo Larsen, U of Nebraska, Lincoln. Electrochemical Promotion in Catalysis: Hydrogenation Reactions and Surface Characterization of a Pt/Cs^+-β" Alumina/Ag Solid Electrolyte Cell. $20,000

Randy W. Larsen, U of Hawaii, Manoa. Conformational Dynamics of Intermolecular Electron Transfer in Proteins. $20,000

David S. Leigh, U of Georgia. Image and Isotope Analysis of Opal Phytoliths in Sedimentary Sequences. $20,000

Andrea J. Liu, U of California, Los Angeles. Theoretical Study of Surface Preferential Attraction in Polymer Systems. $20,000

Peter J. Ludovice, Georgia Inst. of Technology. Application of Structure-Specific Molecular Models to Polyvinylchloride. $20,000

Glenn J. Martyna, Indiana U. Manybody Quantum Dynamics of Molecular Clusters, Liquids and Solids. $20,000

Patricia A. Maurice, Kent State U. Secondary Phase Formation During the Dissolution of Aluminosilicates: An Integrated Approach to Reactivity at the Mineral/Water Interface. $20,000

Alex S. Mayer, Michigan Technological U. Characterization of a Large Fault Zone as a Barrier to Fluid Flow: San Andreas Fault Near Desert Hot Springs, California. $20,000

Mark C. McMills, Ohio U. Metallocarbenoid Intermediates as Useful Tools for Tandem Reactions in Synthesis. $20,000

Anne-Frances Miller, Johns Hopkins U. Superoxide Dismutase: Electrostatic Redox Tuning in Metalloenzymes. $20,000

Karl T. Mueller, Pennsylvania State U. Solid-State NMR Evidence for a Helical Conformation of Lignin. $20,000

Daniel Neuhauser, U of California, Los Angeles. Very Short Range Imaginary Potentials: A Tool for Eliminating Anomalies in Molecular Scattering. $20,000

Ludwig C. Nitsche, U of Illinois, Chicago. Nonlinear Hydrodynamic Drift Effects in Microporous Transport of Colloids and Macromolecules. $20,000

Brooks H. Pate, U of Virginia. Eigenstate-Resolved Correlation Spectroscopy: A Probe of Vibrational Energy Transfer Through Nonbonded Interactions. $20,000

Robert S. Pilato, U of Maryland, College Park. Catalysis by Molybdenum Cofactor Models. $20,000

Jeffrey P. Raffensperger, U of Virginia. Numerical Modeling of Coupled Groundwater Flow, Heat Transport, and Reactive Solute Transport with Application to Diagenetic Cementation by Free Convection. $20,000

Carmelo J. Rizzo, Vanderbilt U. Controlling the Redox Chemistry of Flavins Through Conformational Effects. $20,000

Karin Ruhlandt-Senge, Syracuse U. Synthesis, Structure and Reactivity of Alkaline-Earth and Organoalkaline-Earth Derivatives. $20,000

Steven S. Saavedra, U of Arizona. Molecular Ordering in Hydrated Protein Films Formed by Site-Directed Immobilization. $20,000

Yeon-Kyun Shin, U of California, Berkeley. A Molecular Description of Signal Transduction. $20,000

Masoud Soroush, Drexel U. A Study of Nonlinear State Estimation and Control Issues in Polymerization Reactors. $20,000

Richard J. Spontak, North Carolina State U. Morphological and Phase Studies of $(AB)_n$ Multiblock Copolymers Near the Order-Disorder Transition. $20,000

Gilbert C. Walker, U of Pittsburgh. Infrared Pump/Probe Studies of Protein Conformational Change. $20,000

Peter J. Whiting, Case Western Reserve U. Validation of a More Appropriate Model of Near-Bed Flow and Resistance Over Mixed-Size Beds. $20,000

Angus P. Wilkinson, Georgia Inst. of Technology. Potential Shape Selective Reducing Agents: Microporous Materials Containing Extra-Framework Gallium(I). $20,000

Karen L. Wooley, Washington U. Preparation and Characterization of Water-Soluble Nanoscale Polymer Assemblies: Permanent, Micellar Small Particles. $20,000

Omar M. Yaghi, Arizona State U. Crystalline Microporous Chalcogenides from Molecular Cages. $20,000

David J. Yaron, Carnegie Mellon U. Electron Correlation and the Nonlinear Optical Properties of Polyacetylene. $20,000

Zijian Zeng, U of Hawaii, Manoa. Developing Chemical Agents Hydrolyzing DNA Phosphate Backbone. $20,000

Awarded to faculty in non-Ph.D.-granting departments

Gretchen L. Anderson, Indiana U, South Bend. Interaction of Arsenite with Arsenite Oxidase, a Molybdenum Hydroxylase. $20,000

Paul F. Brandt, Western Carolina U. Synthesis of Ferrocene-Phosphorus Polymers. $20,000

S. Keith Dunn, Centre C. Electronic Energy Transfer from Alkali Halide Substrates to Adsorbed Molecules. $20,000

David C. Easter, Southwest Texas State U. Production, Characterization, and Formation Dynamics of Environmentally Destructive Solvation Clusters. $20,000

Michael R. Gross, Florida International U. Fracture Partitioning in Mechanically Layered Rocks. $20,000

Michael E. Ketterer, John Carroll U. Electron Self-Exchange Rates of Ni(III/II) Redox Couples Measured by Enriched Stable Isotope Labeling Procedures. $20,000

Santanu Khataniar, U of Alaska, Fairbanks. Viscous Fingering and Effect of a Third Hydrocarbon Phase on Displacement of West Sak Oil by CO_2. $20,000

Jian Ma, Amherst C. Adsorption Study of the Microstructure of Sedimentary Rocks. $20,000

Mary M. Mader, Grinnell C. A-Silylacetyl Oxazolidinones as Versatile Precursors to Optically Active Polyols. $20,000

Anna Ploplis Andrews, C of Wooster. Structural Characterization of Connected Polymer Networks. $20,000

Michael H. Schmidt, California State U, San Marcos. Investigations of the Peptide-Mediated Synthesis of Nanometer Semiconductor Crystallites. $20,000

Richard L. Sedlock, San Jose State U. Field-Based Investigations of Mesozoic Rocks Near El Arco, Central Baja California, Mexico. $20,000

Shannon L. Studer, C of Charleston. Molecular Design and Photodynamic Study of Proton/Charge Transfer Molecules. $20,000

Nongjian J. Tao, Florida International U. Surface Charge Induced Structural Phase Transitions of Monolayer Organic Films at Solid-Liquid Interfaces. $20,000

Vladimir Tsukruk, Western Michigan U. Molecular Films from Discotic Liquid Crystals and Polymers. $20,000

Dean A. Waldow, Pacific Lutheran U. Nuclear Magnetic Resonance Measurements of Local Segmental Dynamics of Polymer Blends in Solution. $20,000

ACS-PRF Grants for Fundamental Research in the Petroleum Field (Type SE)

Ken B. Anderson, John C. Crelling, on behalf of ACS Division of Geochemistry, Inc. Amber, Resinite, and Fossil Resins at the 208th ACS national meeting, Washington, D.C., August 1994. $2,000

Peter B. Armentrout, on behalf of ACS Division of Physical Chemistry. Metal-Metal Bonding: From Clusters to Surfaces at the 209th ACS national meeting, Anaheim, Calif., April 1995. $2,000

Christine A.B. Brennan, on behalf of ACS Education Division. ACS Project SEED Supplementary Program. $25,500

David Chandler, Robin M. Hochstrasser, on behalf of ACS Division of Physical Chemistry. Coherence in Condensed Phase Reactions at the 208th ACS national meeting, Washington, D.C., August 1994. $2,000

James V. Crivello, on behalf of ACS Division of Polymeric Materials: Science and Engineering, Inc. UV Curing of Coatings at the 209th ACS national meeting, Anaheim, Calif., April 1995. $2,000

Burtron H. Davis, George D. Blyholder, on behalf of ACS Division of Colloid & Surface Chemistry. Infrared Studies of Surface and Adsorbed Species, in Honor of Dr. Eischens, at the 208th ACS national meeting, Washington, D.C., August 1994. $2,000

Thomas D. Demchuk, on behalf of Coal Division, Geological Society of America. Origin of Compositional Characteristics in Tertiary Coals: Paleoecology, Paleobotany, and Palynology at the Geological Society of America Annual Meeting, Seattle, October 1994. $2,000

Barry L. Farmer, on behalf of ACS Division of Polymer Chemistry, Inc. Computer Modeling of Polymers in the Solid State at the 209th ACS national meeting, Anaheim, Calif., April 1995. $2,000

Warren T. Ford, on behalf of ACS Division of Polymer Chemistry, Inc. Chemical Reactions in Polymeric Environments at the 208th ACS national meeting, Washington, D.C., August 1994. $2,000

Richard D. Gilbert, on behalf of ACS Division of Cellulose, Paper & Textile. Order in Cellulosics at the 207th ACS national meeting, San Diego, March 1994. $2,000

John A. Gladysz, on behalf of U of Utah. Organometallic Chemistry at the Joint 50th Northwest Regional and 12th Rocky Mountain Regional ACS Meeting, Park City, Utah, June 1995. $2,000

John A. Gladysz, on behalf of U of Utah. Metal Complexes of Carbon: Coordination Chemistry of C_x Ligands at the 1995 International Chemical Congress of Pacific Basin Societies, Honolulu, December 1995. $2,000

Anthony Guiseppi-Elie, on behalf of ACS Division of Polymeric Materials: Science & Engineering, Inc. Transducer Active Polymers: Active Components in Sensors and Actuators at the 208th ACS national meeting, Washington, D.C., August 1994. $2,000

C. David Gutsche, on behalf of Texas Christian U. Third International Conference on Calixarenes and Related Compounds, Forth Worth, Tex., May 1995. $2,000

Kathleen O. Havelka, on behalf of ACS Divs. of Polymer Chem., Inc.; Polymeric Materials: Sci. & Eng, Inc. Electrorheological Materials and Fluids at the 208th ACS national meeting, Washington, D. C., August 1994. $2,000

Brian B. Laird, on behalf of ACS Division of Physical Chemisty. Density-Functional Theory in Chemistry at the 209th ACS national meeting, Anaheim, Calif., April 1995. $2,000

Ripudaman Malhotra, on behalf of ACS Divisions of Fuel Chemistry and Petroleum Chemistry, Inc. Hydrogen Transfer in Hydrocarbon Processing at the 208th ACS national meeting, Washington, D.C., August 1994. $2,000

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CHEMICAL & ENGINEERING NEWS

C&EN

SEPTEMBER 5, 1994

SCIENTIFIC NEWS FROM THE WASHINGTON ACS NATIONAL MEETING

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Chemical syntheses that don't pollute
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CHEMICAL & ENGINEERING NEWS

C&EN

SEPTEMBER 5, 1994

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- EPA proposes rule defining how it will regulate genetically modified organisms under the Toxic Substances Control Act and issues final rule on field testing of bioengineered microbial pesticides. Page 5
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- U.S.-China commercial ties and U.S. chemical exports to China get major boost from mission to China led by Secretary of Commerce. Page 6
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Editor: Michael Heylin (202) 872-4501
Managing Editor: Madeleine Jacobs
Assistant Managing Editors: Rudy M. Baum, Ernest L. Carpeiter, Janice R. Long, Rebecca L. Rawls, William J. Storck
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LETTERS

Impairment versus drug testing

An increasing number of chemists and chemical engineers are being subjected to random drug tests. Initially limited to workers in positions with unique safety concerns, testing is slowly expanding to include other jobs. In 1991, DuPont abandoned plans to test engineering department employees after many of them expressed concern over testing errors, invasion of privacy, and the potential degradation of employee-management trust.

In light of the grave damage to career and reputation that can occur from testing error, participants need to be aware of the myriad routes through which mistakes can occur. C&EN (Aug. 8, page 56) recently noted that poppy seed consumption can lead to the misdiagnosis of heroin use. I have previously reviewed the metabolic and procedural chemistry underlying this and other drug misidentifications (*CHEMTECH*, Sept. 1992, page 523).

In an example from the chemical industry, the urine of a Laporte, Tex., worker incorrectly tested positive for methamphetamine when a National Institute for Drug Abuse (NIDA)-certified testing laboratory misdiagnosed the legal decongestant pseudoephedrine—present in more than 100 over-the-counter medications—as an illicit drug. For months, the innocent employee was treated as a drug abuser. A second false positive has been uncovered involving another employee at the same company.

A pilot at a major U.S. airline lost his job after testing positive for opiates, the source of which was later determined to be aspirin purchased in Canada, which, unknown to him, contained codeine as a legal part of the drug formula (*Aviation Safety*, June 15, 1993, page 6). Following the *Exxon Valdez* oil spill, blood samples drawn from Capt. Hazelwood by the U.S. Coast Guard and placed in 15-mm test tubes with gray stoppers were recorded by Compuchem, a NIDA-certified testing laboratory, as having arrived in 10-mm test tubes with red stoppers. After the laboratory measured a 0.06% blood alcohol level, Hazelwood was indicted. But Compuchem did not inform Hazelwood of the anomaly in the chain-of-custody or of changes to the documentation made five weeks later (*New York Times*, July 28, 1990, page 7). Even sample spiking or data falsification are possible. Workers at one testing laboratory were convicted of fabricating positive drug test results (C&EN, June 29, 1987, page 19).

DuPont-funded studies by the American Association of Clinical Chemistry indicate that a false positive rate of one per 700 urine samples can be achieved by using two testing procedures to enhance accuracy [*Clin. Chem.*, **33**, 1682 (1987); **35**, 891 (1989)], and all NIDA-certified laboratories use such procedures. No peer-reviewed scientific studies have been published indicating that lower error rates are presently attainable.

When safety is an issue, a more informative and more dignified alternative to random drug tests is available—impairment tests. These quick and inexpensive tests provide immediate feedback and can be administered daily to detect impairment by any cause, including fatigue, illness, or drugs. A blue-ribbon panel sponsored by the National Research Council recommends that industry more seriously consider their use in place of random drug tests for workers in safety-sensitive positions ("Under the Influence? Drugs in the American Work Force," National Academy Press, Washington, D.C., 1994). The *Exxon Valdez* oil spill, brought about by the impaired performance due to fatigue of the operator steering the ship, might have been avoided if such tests were in use.

I recently had the opportunity to try out one such test offered by Performance Factors, Oakland, Calif. I was impressed by the speed and simplicity of this computer-controlled hand-eye coordination test. Based on technology developed to study pilot performance under adverse conditions, scientific studies have shown the results to correlate with levels of alcohol and drugs in the blood [*Psychopharmacology*, **85**, 51 (1985)]. Another test analyzing for cognitive skills is offered by Essex, Columbia, Md.

The American Medical Association has provided a thoughtful critique of random drug testing, recommending that impairment testing be used in its place [*J. Am. Med. Assoc.*, **264**, 1039 (1990)]. Their general counsel, David Orentlicher, writes: "In some way, there can be an important symbolic value when a hospital effectively declares zero tolerance for drugs by instituting urine drug testing. However, the symbolism may have unintended effects. While the hospital tells its patients they are receiving the most effective treatments for their diseases, it is employing a less-than-optimal method for detecting physician impairment. . . . Hospitals should be careful not to abandon other

Continued on page 46

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ganisms in different genera. The rule requires persons intending to manufacture, import, or process intergeneric organisms for commercial purposes to file a Microbial Commercial Activity Notice (MCAN) with EPA at least 90 days before undertaking such activity. Introduction of such organisms into the environment for commercial R&D purposes requires 60 days' advance notification.

EPA also proposes to exempt from the MCAN requirement 10 microorganisms commonly used in contained fermentation systems to make specialty chemicals, particularly enzymes. R&D testing of intergeneric microorganisms would be exempt from EPA oversight when tests are conducted in contained structures, such as greenhouses or labs.

The final rule on field testing changes the current requirement of advance notification to EPA for even small field tests of genetically modified microbial pesticides. The new rule, issued under the Federal Insecticide, Fungicide & Rodenticide Act, exempts from the requirement small-scale field tests of organisms in which the genetically induced changes are similar to those that occur in nature.

"We're delighted that the agency has persevered and gotten these rules out," says an Environmental Defense Fund spokeswoman. This "is a big step forward . . . because for the first time EPA will actually have rules covering biotechnology products."

A spokesman for BIO, the Biotechnology Industry Organization, couldn't comment in depth on the proposed rule because he hadn't seen it, but says, "We're happy to have a proposed rule to study and comment on. It's been quite a period of time under development." He points out that EPA has been operating under a 1986 policy statement to regulate biotechnology products. "Clearly, they can do that," he says. "But there are a lot of nuances as to how they implement the policy" that need to be defined by regulation. The rules were published in the Sept. 1 *Federal Register*.

Janice Long

U.S. seeks to boost chemical sales to China

U.S.-China commercial ties and U.S. exports to China, including chemical exports, have been given a major boost by a just concluded seven-day mission to China and Hong Kong led by Secretary of Commerce Ronald H. Brown.

The Presidential Business Development Mission to China was the first Cabinet-level visit since the Clinton Administration renewed "most favored nation" trade status for China in May and decoupled trade relations from China's human rights policies (C&EN, May 30, page 7). Brown was accompanied by two dozen chief executive officers from major U.S. corporations, including Atlantic Richfield, Chrysler, Eastman Kodak, Fluor Corp., Foster Wheeler, TRW, and Westinghouse.

Delegation members met senior Chinese officials to advance cooperation on bilateral issues, such as protection of intellectual property and market access. The CEOs also discussed business agreements with the Chinese and signed contracts totaling several billion dollars.

A central focus was signing of a "historic framework agreement" by Brown and Wu Yi, China's Minister of Foreign Trade & Economic Cooperation, who cochair the U.S.-China Joint Commission on Commerce & Trade (JCCT). Under the agreement, JCCT bilateral working groups will foster cooperation in several sectors, including chemicals, electronics, electric power, telecommunications, aviation, automotive machinery, and services. Similar cooperation is envisioned in envi-

Sales brisk for ACS Publications on Disc

Susan Barclay of ACS Publications Division displays a page with a full-color illustration from the CD-ROM version of *Biochemistry*, one of two journals in the just-released ACS Publications on Disc series. A month after the first discs were shipped, sales are brisk for both *Biochemistry* and the *Journal of the American Chemical Society*, says Anthony Durniak, head of ACS Special Publications. "Judging from initial interest in these two CD-ROM journals, we expect to expand the series to include many of the 24 ACS journals," he says. Unlike many text-only or bibliographic CD-ROMs, the ACS discs deliver complete journal pages, including typeset text, chemical equations, and all illustrations. Sophisticated graphics allow users to view entire articles on screen or to print them in black and white or color on their printers. *Biochemistry* is distributed on disc every two months, and *JACS*, every three months. The discs include the complete text and graphics of issues in that period, as well as cumulative indexes and text for that year. One disc user, professor of chemistry David E. Bergbreiter of Texas A&M University, says the "very fast search feature" speeds up literature searches. Readers can search by author or topic, for key words in the title or abstract, or in a combination of categories. The discs give "very high quality prints," he adds, and are "better archival forms than journals, because you can store 10 years' worth of journals in a few inches of shelf space."

C&EN staff photo

CD-ROM subscriptions, available in Windows or Macintosh versions, can be ordered alone or with a subscription to the printed journal. Order information may be obtained from Barclay at (202) 872-6219.

Madeleine Jacobs

Fertilizers, organic chemicals, and plastics top U.S. chemical exports to China

	1993		January–May 1994	
$ Millions	Exports	Imports	Exports	Imports
Fertilizers	$293	$ 0	$229	$ 0
Organic chemicals	204	127	91	70
Primary plastics	168	16	72	3
Dyeing & coloring materials	29	39	16	16
Pharmaceuticals	27	126	9	60
Inorganic chemicals	25	134	19	84
Nonprimary plastics	22	6	7	3
Oils, perfumes & cleansing products	21	35	9	14
Other chemical materials & products	51	92	24	51
TOTAL CHEMICAL TRADE	$840	$575	$476	$301

Source: Department of Commerce

ronmental and health care technologies. "These all are areas that meet China's development priorities and in which U.S. business excels," Brown points out.

Fred Siesseger, director of the chemicals, pharmaceuticals, and biotechnology division at the Commerce Department, tells C&EN that efforts in the chemicals sector served as a model for organizing working groups in other sectors. The chemical group is led on the U.S. side by his office and on the Chinese side by the Ministry of Chemical Industry.

The chemical group's activities will embrace two areas, Siesseger notes: commercial issues—both obstacles and opportunities for U.S. trade and investment in China—and promotion of U.S. exports to China.

One of the commercial issues to be addressed at the first meeting of the chemical group, planned for later this month in Beijing, involves "very serious problems created by China's new environmental regulations," he says. "As currently drafted, they could disrupt almost $1 billion in chemical imports from the U.S." The group also will discuss intellectual property protection and market access in China as well as "market transparency"—that is, development of a business information center to supply information on trade and investment opportunities for U.S. companies.

Discussions at the Beijing meeting also will focus on ways of promoting U.S. chemical exports, such as trade missions, conferences and seminars, and trade shows. Siesseger notes that these efforts will build on cooperation already developed with the Chinese by his office, including a successful one-week trade mission to China last month by U.S. firms that make water treatment chemicals and equipment, as well as a coatings technology mission last year.

Next week, a delegation of nine leading U.S. suppliers of plastics additives plans to visit Shanghai and Beijing. Two-day technical seminars will be presented for some 150 to 200 Chinese industry officials at each city. A mission on plastics is scheduled for November, and one on food-processing chemicals for next spring. And the Beijing meeting will look at organizing a mission on pollution control for chemical industry.

So much is planned because "China is the fastest growing chemical market in the world," Siesseger stresses. "I think it's the linchpin for trade and investment in Asia. And many companies are starting to realize that if they want to be global players, they have to participate in the China market."

Richard Seltzer

NIH spurs research on novel AIDS therapies

A new multi-million-dollar program to push development of innovative therapies to fight infection by the human immunodeficiency virus (HIV), the cause of AIDS, has been launched by the National Institute of Allergy & Infectious Diseases (NIAID), a unit of the National Institutes of Health, Bethesda, Md.

NIAID's Strategic Program for Innovative Research on AIDS Treatment (SPIRAT) will support six research teams for four years, each team consisting of three or more investigators from at least three U.S. institutions. NIAID has awarded a total of $6.2 million for the first year of the program, with similar support projected for subsequent years. The teams are to begin early studies in humans by the third year, at the latest.

SPIRAT "provides an important bridge between basic and clinical research and offers the potential for the development of effective, long-term treatments for HIV-infected people," says John Y. Killen, director of the NIAID Division of AIDS. "The state-of-the-art strategies proposed by the research groups are conceptually exciting and scientifically well grounded."

The program will support a variety of research:

- Philip D. Greenberg, a member of the Fred Hutchinson Cancer Research Center, Seattle, will use genetic manipulation to bolster the function of lymphocytes known as $CD8^+$ and $CD4^+$ T cells from HIV-infected individuals.
- Judy Lieberman, an assistant professor of medicine at Tufts University School of Medicine and a physician at the New England Medical Center, Boston, will use "adoptive immunotherapy," which combines immune cells with cytokines, to augment the immune system's capacity to eliminate HIV-infected cells.
- Thomas C. Merigan, a professor of medicine at Stanford University, will explore a similar adoptive immunotherapy technique that infuses immune cells from donors without HIV infection into their HIV-infected siblings.
- Gary J. Nabel, a principal investigator at the Howard Hughes Medical Institute, Ann Arbor, Mich., will investigate a gene therapy strategy for children that harnesses a defective HIV *rev* gene to attempt to prevent the virus from killing $CD4^+$ T cells.
- Flossie Wong-Staal, a professor of medicine and biology at the University of California, San Diego, will study a type of gene therapy that uses a gene for a ribozyme designed specifically to cleave and inactivate a portion of HIV's genetic material.
- David Weiner, an assistant professor of pathology and laboratory medicine at the University of Pennsylvania Medical Center, will explore DNA-based therapeutic vaccines, including methods to facilitate the effectiveness of DNA injection techniques.

NIAID also has renewed grants to 12 sites and added four new sites under its Community Programs for Clinical Research on AIDS (CPCRA). First-year funding for the 16 five-year awards totals $12 million. CPCRA, which began in 1989, offers HIV-infected patients the opportunity to participate in clinical trials of HIV therapies in community settings such as private practices, clinics, and health centers. With the four new sites, CPCRA will have units in 15 cities. More than 15,000 patients have enrolled in 23 trials.

Rudy Baum

New actions to prevent chemical accidents urged

Fundamental steps by federal, state, and local governments and industry to prevent chemical accidents—rather than programs "preoccupied with accident mitigation and emergency response"—are urged in an analysis of U.S. toxic chemical accidents issued last month by two consumer and environmental groups.

The 25-page report, "Accidents Do Happen," was prepared by the National Environmental Law Center (NELC), based in Boston, and the U.S. Public Interest Research Group (PIRG), based in Washington, D.C. The report examines chemical accidents from 1988 to 1992 using data from the Environmental Protection Agency's Emergency Response Notification System (ERNS)—based primarily on initial telephone reports of accidents to authorities. ERNS is the largest and most comprehensive database on U.S. chemical accident notifications and covers both transportation and plant accidents.

The study includes incidents involving some 800 toxic and hazardous chemicals regulated under federal laws. It excludes oil, gasoline, and other petroleum product spills—which constitute 52% of ERNS notifications.

The report finds that "toxic chemical accidents are a common, ongoing problem with potential for catastrophe." Almost 34,600 incidents were reported to ERNS from 1988 to 1992. About 6% resulted in deaths, injuries, or evacuations.

ERNS data show release of more than 680 million lb of toxic chemicals into the environment from these accidents. However, the report says, even this large number "is a gross underestimate." A third of ERNS notifications give no estimate of quantities, and many accidental spills are not reported. Almost 10% of reported incidents involved releases of more than 10,000 lb.

About 47% of the accidents emitted toxic chemicals to land, 38% to air, and 15% to surface waters. And in data not in the report, coauthors Joel A. Tickner and Hillel Gray of NELC find 75% of the releases occurred at plants and other fixed facilities, 8% on roads, 5% on railroads, 3% from pipelines, and 8% from other, or unclassified, sources.

Almost two thirds of the accidents involved one of 15 chemicals. Heading the list with almost 3,600 accidents are polychlorinated biphenyls.

More than half the accidents occurred in 10 states, led by California and Texas, with Louisiana third. Just 63 of the U.S.'s 3,181 counties account for more than 40% of the incidents. Ranking first is Harris County, Texas, which includes Houston. It is followed by Los Angeles County, California; Jefferson County on the Texas Gulf Coast; Calcasieu County in the Lake Charles, La., area; and San Diego County, California.

Environmental groups view the report as "a wakeup call" for political and industry leaders, Tickner tells C&EN. The study notes that chemical safety programs and two federal agencies overseeing them—EPA and the Occupational Safety & Health Administration—"are more geared to conventional accident mitigation and add-on safety systems than fundamental prevention."

Two states have 27% of toxic chemical accidents . . .

	Accidents 1988–92	
	Total	With injuries[a]
California	4,820	409
Texas	4,532	176
Louisiana	2,505	60
Pennsylvania	1,395	78
Ohio	1,269	84
Kentucky	1,166	36
Illinois	1,085	64
Florida	905	84
Michigan	869	50
New Jersey	857	64
Others	15,172	1,081
TOTAL[b]	**34,575**	**2,186**

. . . and PCBs lead list of chemicals released

	Accidents 1988–92	
	Total	With injuries[a]
Polychlorinated biphenyls	3,586	34
Ammonia, anhydrous	3,333	389
Sulfuric acid	2,387	130
Chlorine	2,099	409
Hydrochloric acid	1,504	143
Ethylene glycol	1,470	18
Sulfur dioxide	1,310	86
Radioactive materials	1,073	30
Benzene	1,048	14
Hydrogen sulfide	939	49
TOTAL[c]	**18,749**	**1,302**

[a] Accidents resulting in immediately reported deaths, injuries, or evacuations but excluding chronic health and environmental effects. [b] For all 50 states, Puerto Rico, District of Columbia, Virgin Islands, and Guam. [c] For top 10 chemicals released (but many accident notification forms do not properly identify all chemicals released). **Source:** Emergency Response Notification System database (1988–92), compiled by the National Environmental Law Center and U.S. Public Interest Research Group

A better approach, the report stresses, is to prevent accidents through the relatively new principle of "inherent safety" or "primary accident prevention"—redesigning industrial processes "to be inherently more safe and involve less toxic materials." NELC and PIRG urge federal, state, and local agencies and industry to make "aggressive efforts to promote inherent safety," and to set numerical goals for reducing chemical accidents. They call on federal and state agencies to greatly improve public access to data on accidents, toxics use, and potential "worst case" accident hazards.

A key recommendation—also backed by the Oil, Chemical & Atomic Workers International Union—is that the Administration start up promptly, with adequate funding, the Chemical Safety & Hazard Investigation Board. Established by the Clean Air Act Amendments of 1990, this five-member board is charged with investigating chemical accidents and conducting research on chemical safety and accident prevention.

However, four years after its establishment, the board is still not functioning. A chairman and three members have just been named and await Senate confirmation (C&EN, Aug. 1, page 25). It's expected that a fifth member, with industry background, will be announced soon. But Congress is so far holding back on funding, originally projected at about $5 million a year, with a staff of 30. NELC and PIRG believe this independent board, reporting directly to the President, could be "a motivating force in the shift toward inherent safety."

Responses to the report from chemical industry and EPA generally take a positive tone. Don Helin, director of safety, health, and operations for the Chemical Manufacturers Association, notes that the chemical sector is consistently among the three safest U.S. industries, but "we are always trying to improve our performance." Craig Matthiessen, director of the chemical accident prevention staff at EPA, says, "We're very supportive of the recommendations in the report. It's what we're trying to do."

Richard Seltzer

Chemists Ponder Reforms To Organic Chemistry Curriculum

■ ***Survey suggests it's time to 'prune' outmoded topics, but is there room to teach environmentally benign chemical synthesis?***

208 ACS National Meeting
Washington, D.C.

Deborah L. Illman,
C&EN West Coast News Bureau

Like miners tunneling their way through a mountain beginning from different sides, the question is, will efforts to reform the organic chemistry curriculum meet up, or will they pass each other by?

The content of the organic chemistry curriculum was discussed in two separate symposia at the ACS national meeting in Washington, D.C. One, entitled "Examining the Organic Chemistry Lecture Course," was sponsored by the Division of Chemical Education. The other was a part of the wide-ranging "Design for the Environment" symposium sponsored by the Division of Environmental Chemistry. There's evidence to suggest that the two groups of reformers may not be on convergent paths.

"Environmentally Benign Syntheses and Processes in the Chemistry Curriculum" was organized by Paul T. Anastas and Tracy C. Williamson, of the Environmental Protection Agency, and Margaret A. Cavanaugh, a program director in the chemistry division of the National Science Foundation.

Anastas and Williamson say the changing nature of chemical manufacturing in the 1990s has created the need to address curriculum reform. They point out that synthetic chemists are the key practitioners in identifying, developing, and implementing actual source reduction technologies. Those same chemists are now being challenged to incorporate pollution prevention into everyday practices.

"When designing the synthesis of a chemical substance," according to Anastas and Williamson, "chemists must now consider the hazards associated with starting materials, solvents, catalysts, coproducts, by-products, or any other chemicals used in or formed from all reactions of a particular synthetic scheme."

The problem, Anastas says, is that pollution prevention principles generally have not been incorporated into the chemistry curriculum. As a result, EPA has launched what it calls the Benign by Design Chemistry Curriculum Program. The program is funding efforts at the National Pollution Prevention Center at the University of Michigan, Ann Arbor, and the Emission Reduction Research Center at the New Jersey Institute of Technology, Newark, to develop general education materials that do incorporate such principles.

But it doesn't seem that an environmental sensibility has yet made its way into the mainstream organic chemistry community. "Green" chemistry was not a focus of attention in the chemical education symposium.

Nevertheless, rumblings of change were stirring. In his talk titled "Introductory Organic Chemistry—A Basket Case!?" Samuel S. Stradling, of the chemistry department at St. Lawrence University, Canton, N.Y., maintained that "the content and teaching of intro-

Faculty would keep most organic chemistry topics . . .

- Alkanes
  - Combustion
  - Free radical halogenation
- Alkenes
  - Addition, hydrogenation
  - Hydration, oxidation
  - Free radical reaction
- Alkyl halides
  - Substitution, elimination
- Alcohols
  - Alkoxide formation
  - Oxidation, conversion to HX
  - Dehydration
- Aldehydes and ketones
  - Addition of water, alcohols, amines
  - Reduction, Wittig reaction
- Alkynes
  - Reduction, addition of HX
- Aromatics
  - Halogenation, Friedel-Crafts
  - Nitration, sulfonation, oxidation
  - Addition to naphthalene
- Dienes
  - Diels-Alder
  - Addition of halogens and halides
- Carboxylic acids and derivatives
  - Reduction, Grignard
  - Hydrolysis, acyl halides
- Enols
  - Aldol, crossed aldol
  - Claisen, Dieckman, Michael reactions
  - Malonic ester synthesis
- Amines
  - Alkylation, acidity
  - Hofmann elimination
  - Aromatic amines
  - Aryl diazoniums
- Organometallics
  - Grignard, alkyllithiums
- Others
  - Carbohydrates, amino acids

. . . and would drop precious few

- Biochemical reactions
- Esoteric name reactions
- Concerted reactions except Diels-Alder
- Advanced spectroscopy
- Reactions of sulfur compounds
- Functional group tests

Note: Based on a survey by Marco Pagnotta, Columbia University, and colleagues of about 200 schools nationwide, which asked organic chemistry professors to choose topics that should be excluded from the curriculum.

ductory organic chemistry has deservedly been under siege for some time. Nonetheless, change has been slow to occur." In his classes, Stradling uses case studies on topics such as taxol, the ozone layer, and aspirin to enrich the presentation of introductory organic chemistry.

Results of a new nationwide survey of chemistry faculty about topics that should be retained in organic chemistry textbooks and courses that should be taken out were presented by Marco Pagnotta, of Barnard College, Columbia University, New York City. Pagnotta conducted the study with John P. Wasacz, of Manhattan College, Riverdale, N.Y., and Leslie A. Hull, of Union College, Schenectady, N.Y.

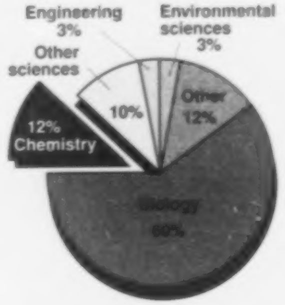
Pagnotta and his coworkers set out to explore whether there is a consensus among instructors of organic chemistry on course content. A survey sent to about 200 schools asked respondents to choose from a list of specific topics those they thought could be omitted from either the lecture, the text, or both. Responses were obtained from 56 of 99 surveys sent to primarily undergraduate institutions, as well as from 44 of 102 surveys sent to schools with graduate programs.

Respondents were quicker to cut items from the course syllabus than from textbooks, thereby keeping a wide range of resource material available. Pagnotta says the topics receiving the strongest vote of confidence were stereochemistry and substitution, elimination, and addition reactions. Topics that could be cut included biochemical reactions, esoteric reactions, advanced spectroscopy, reactions of sulfur compounds, and functional group tests.

Enrollments in organic chemistry are increasing at 72% of responding institutions. But declared chemistry majors are in the minority: 60% of students enrolled in organic chemistry classes are biology majors, and only 12% are chemistry majors. Pagnotta concludes that most students take organic chemistry to satisfy requirements of other departments.

Some symposium presenters tell C&EN that the pedagogic value of traditional topics outweighs environmental considerations, and therefore, conventional topics should be kept despite the fact they may not be considered environmentally benign. And some argue that the curriculum is just too full to address principles of green chemistry.

Chemistry majors are a minority in organic classes

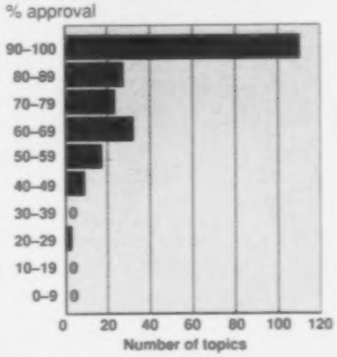


If the organic chemistry curriculum is already overfull, and if faculty place priority on traditional reactions and topics, can there be any common ground with those who would modernize the curriculum to be "benign by design"? Anastas believes "there is an increasing number who say yes."

Adding environmentally benign chemistry "is not about putting another layer of material on top of the chemistry curriculum," asserts Anastas. "It is about recognizing that some of the existing synthetic methodologies and some of those yet to be discovered are more environmentally benign than others."

Frank Vellaccio, vice president of academic affairs at the College of the Holy Cross, Worcester, Mass., contends it is time to question whether what is being taught in introductory chemistry contributes to the common good. He suggests that social values and environmental ethics are valid motivating factors for including material in the introductory curriculum.

Organic chemistry profs would keep most topics



Note: Results of a survey of organic chemistry faculty on which of 237 topics should be retained in the organic chemistry curriculum.

Francis A. Carey, a chemistry professor at the University of Virginia, Charlottesville, points to some good reasons for including "benign by design" in organic courses. "If chemists don't demonstrate that the chemical community is committed to good stewardship, then who will?" he asks.

Carey further notes that the timing is right: Students these days tend to be environmentally conscious, and curriculum material targeting pollution prevention introduces important ideas that connect chemistry to economic and environmental concerns.

Meanwhile, the National Pollution Prevention Center (NPPC) at the University of Michigan, Ann Arbor, is planning to launch a program this year aimed at developing laboratory experiments, text supplements, and a compendium of resource materials for organic and inorganic chemistry courses relating to the design of environmentally benign chemical synthesis.

NPPC manager Gregory A. Keoleian says that a set of materials for chemical engineering has been under development for some time and will be available this month. Some of the education materials include problem sets, case studies, and videotapes, available at nominal cost, that can be used in chemical engineering courses.

Researchers at the Emission Reduction Research Center have been working for some time to develop curriculum materials for engineering, social sciences, and humanities that deal with pollution prevention. For the past year, the center has been working with an industrial partner to develop training experiences for industrial chemists in pollution prevention. Center director Daniel J. Watts says their approach involves raising the consciousness of chemists about manufacturing processes and the pollution problems associated with them.

EPA's Williamson believes industry will be a driving force for incorporating green chemistry into the curriculum, because otherwise, companies will have to devote time and resources to retraining personnel. Others believe that graduate research on environmentally benign synthesis will create a "trickle-down" effect, eventually showing up in the undergraduate curriculum. ☐

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CHEMICAL & ENGINEERING NEWS

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SEPTEMBER 12, 1994

NEWS OF THE WEEK

- A chemist and a biochemist are among eight scientists selected to receive the 1995 National Medal of Science. **Page 4**
- A federal judge approves a $4.2 billion silicone breast implant settlement. **Page 4**
- Scientists predict stratospheric ozone depletion will get worse before ozone begins a slow recovery around 1998. **Page 5**
- Princeton University chemists develop a new process that uses a titanium compound to reduce polychlorinated biphenyls, producing biodegradable compounds. **Page 5**
- Two research groups announce independent syntheses of balanol, a natural product that is a potent inhibitor of protein kinase C enzymes, which are linked to a variety of diseases. **Page 6**
- EPA proposes stricter air pollution standards for municipal waste incinerators to reduce emissions of metals, acid rain precursors, and dioxins. **Page 7**
- Johnson & Johnson and Eastman Kodak reach an agreement for J&J to acquire Kodak's clinical diagnostics business for $1.01 billion. **Page 7**

COVER: Painting of Antoine-Laurent Lavoisier and his wife, by Jacques Louis David. The Metropolitan Museum of Art, Purchase, Mr. and Mrs. Charles Wrightman Gift, in honor of Everett Fahy, 1977. Copyright 1989 by the Metropolitan Museum of Art

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BUSINESS

Silicone chemicals producer OSi Specialties—after more than a year on its own—plans to build on niche markets and technology to pay down debts, according to chairman David Barton. **Page 11**

Prospects are bright for Western Europe's petrochemical industry, but restructuring is needed to address overcapacity issues. **Page 13**

GOVERNMENT

From the ACS meeting in Washington, D.C.: Moving away from the Delaney clause seems inevitable, but Congress may not be so eager to do so because of public pressure. **Page 16**

Calls made to tighten safeguards, lower thresholds for detecting diversion of fissile material to stop nuclear thefts. **Page 17**

SCIENCE/TECHNOLOGY

Experimental chemistry and research needs are influencing software development, as indicated by new products introduced at exposition held during the recent ACS meeting. **Page 21**

New semiconducting materials are being heralded as novel electro-optic devices for use in energy saving systems. **Page 28**

From the ACS meeting: Polycyanurate resins continue to find useful applications, although the mechanism leading to polymerization still puzzles researchers. ■ Novel Raman microprobe spectroscopy technique is used as a diagnostic tool to probe silicone in tissue from breast explants. **Page 30**

EDUCATION

Chemical educators in developing countries are reaching more students through partnerships and "distance learning." **Page 35**

ACS NEWS

ACS Council adopts petitions on election matters and membership requirements during its meeting in Washington. ■ ACS News Service celebrates its 75th anniversary. **Page 49**

SPECIAL REPORT

Careful study of Antoine Lavoisier's day-to-day practice of chemistry reveals a scientist who—like his modern counterparts—had to feel his way into the unknown, learned what he was doing as he did it, and knew in advance just enough to take the next step in his work. Page 38

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LETTERS

CHEMICAL SAFETY

Hazard in hydrosilylation of D_4^{Vi} with D_4^{H}

We have read with interest the safety notification by DuPont and GE researchers [Potential hazard in hydrosilylation of D_4^{Vi} with D_4^{H} (C&EN, April 25, page 4)], and wish to comment that uncontrolled exotherms or explosions have been observed with vinylic silanes or siloxanes as the sole reactant. For example, thermal exposure of commercially available vinyl silanes in closed containers to about 200 °C has been noted to cause extremely rapid pressure increases to greater than 500 psig.

Thus, any chemistry involving significant concentrations of vinyl silicon compounds, that also involves elevated temperatures, as may occur during exothermic reactions, should be performed using the precautions recommended.

Curtis L. Schilling
Frank D. Mendicino
OSi Specialties
Sistersville, W.Va.

Plea for tolerance, balance

Immediately below the heading "Ethics, responsibility in science" (C&EN, July 25, page 4) there is a letter that criticizes C&EN for its handling of the fraud relating to the alleged control of enantioselectivity by a magnetic field.

I found C&EN commendable both in its editorial and news article (June 27, pages 3 and 7) and feel impelled to respond to the letter, which contains the sentences: "A large share of responsibility rests on the professor in charge who should have supervised and demanded ironclad evidence. We have already learned from the polywater, cold fusion, and immunological dilution episodes that editors of some scientific journals are more interested in publicity than reliability."

I agree completely with the first sentence of the quotation, but not the second. As a longtime reader of *Angewandte Chemie,* in which the article on the effect of the magnetic field was published, I believe that *Angewandte Chemie* is a journal of quality, reliability, and integrity.

Many ACS members serve as referees for one or another of the society's journals. Had we been assigned by an editor to referee that article, without the advantages of hindsight but on the basis of presented evidence, would we have denied its publication? I think not.

Furthermore, such fraud would not have occurred in an industrial chemical laboratory. The purported discovery would have initiated a series of meetings with patent attorneys and with management, accompanied by invention reports and demands for and execution of reduction to practice. Publication would had been delayed, and the initiator of the fraud discovered and fired. Industrial laboratories are not perfect, but the type of fraud being discussed here occurs, albeit infrequently, in academic laboratories and the reasons for it are outside the scope of this letter.

Those of us who perform as referees know that it is quite easy to referee articles where the scientific advance is in an established field. All too frequently, such

Corrections

- Aug. 22, page 47: R&D spending by Lubrizol in 1993 was $89 million, not $172 million. The company's R&D spending as a percent of sales for 1993 was 5.8%, not 11.3%. Total R&D spending in 1993 for the 16 chemical firms included in the table was $4,133 million, a change of –5% from 1992. Total 1993 R&D spending as a percentage of sales for these firms was 4.3%.
- Aug. 22, page 65: The number of master's degrees awarded in chemistry in the 1991 academic year was 1,665, not 1,165.
- Aug. 22, page 66: Foreign graduate students accounted for 32% not 25% of the total full-time graduate students in the sciences and engineering in 1992.
- Aug. 22, page 77: Barry M. Trost's affiliation was misstated. He is at Stanford University.

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the last half-penny a pound out of production," as larger commodity producers do. And he does not think OSi should be in both commodity and specialty chemicals, "because that gets confusing."

With clear insight into the specialty nature of OSi's business, Barton is confident that OSi will outgrow its debts and prosper as an independent specialty chemicals company. It will do so because OSi "provides technical service in support of product development that creates value on the customer's end," and, he could add, profits to pay down OSi's debt. ☐

European petrochemicals up; problems remain

The Western European petrochemical industry's prospects for 1994 are brighter—"after three difficult years," states Jukka Viinanen, president of the Brussels-based Association of Petrochemicals Producers of Europe, in APPE's just-published annual review of 1993–94.

The industry is seeing "encouraging signs of recovery," says Viinanen, who is also on the board of directors of Finnish oil producer Neste Corp. He cites a fistful of reasons: some improvement in demand; a more favorable trade balance for petrochemicals in Western Europe; olefin production at record levels, increasing plant capacity utilization rates; and a reduction in raw material costs that, coupled with some increases in petrochemical prices, showed up as improved profitability in the industry's first-quarter operating results.

According to APPE's first-half 1994 statistics, for example, production of ethylene was up 10% over first-half 1993, to 8.48 million metric tons, spurred by strong growth—13%—in the second quarter. For propylene, production in the half was up 11% to 5.02 million metric tons, as growth in output of 11% propelled each of the first and second quarters. For butadiene, strong second-quarter performance spurred growth of 8% in output in the first half, to 926,000 metric tons.

But even more than increased production driven by improving market conditions, Viinanen cites some structural improvements in the industry. For example, two new olefin crackers have gone on stream, the last in a wave of investments in new crackers that began in Western Europe in the late 1980s. The startups were followed by announcements of the closure of two less economical crackers. That, he says, has helped provide "real evidence that the competitiveness of the Western European petrochemicals industry has improved."

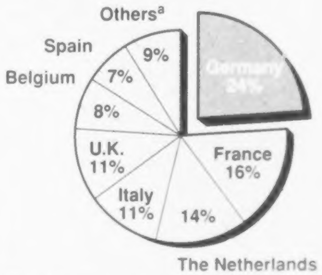
There is still much to be done, however. "The industry as a whole has far to go before an acceptable and sustainable level of return on capital employed is achieved and a climate for new investment is established," says Viinanen. "Above all, much remains to be done in resolving the well-recognized structural problems that are inherent in the Western European petrochemical industry. I fervently hope that a return to better times will not decrease the determination of the industry to find ways of resolving the difficult structural problems that it faces."

That hope is shared by others in the industry. According to John K. Robinson, chief executive of Cleveland-based BP Chemicals' performance and industrial products division, "Our fear is that this temporary good time will prevent companies from taking positive action to contribute to restructuring the industry."

Robinson was speaking specifically about the market for ethylene derivatives glycol and oxide, although he could have been speaking about other sectors in the industry as well.

He acknowledges "a real shortage" globally in ethylene glycol and ethylene oxide, because of several factors: planned and unplanned shutdowns, a

Germany tops European cracking capacity



Total European cracking capacity = 19.1 million metric tons

a Includes Austria, Finland, Greece, Norway, Portugal, Sweden, and Switzerland. **Source:** Association of Petrochemical Producers of Europe

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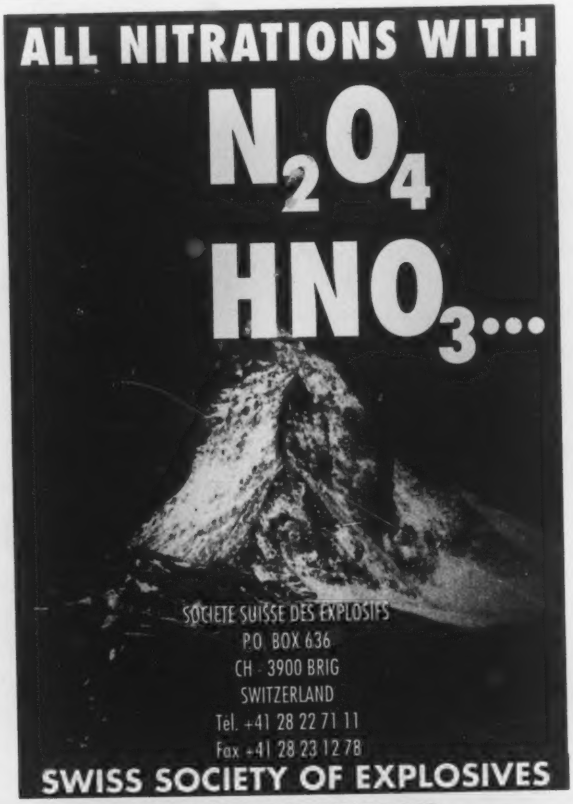

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high demand for polyethylene terephthalate and polyester, and a seasonal inventory stocking for antifreeze. The result is that prices are up dramatically. Prices for ethylene glycol are expected to be 20 to 30% higher by the fourth quarter of this year, and those for ethylene oxide, 30 to 40% higher.

The ability to push through price increases is easing producers' problems, says Robinson, who notes that BP Chemicals showed a $100 million loss in 1993 on the glycol and oxide businesses.

The current shortages, however, won't solve underlying structural weakness, he adds. The shortage in ethylene oxide, for example, is expected to last "for more than six months but less than 12," by which time supply will have rebounded. By that time, Robinson gloomily predicts, producers will be back to operating with low 80% capacity use.

The only long-term answer is to take out excess, inefficient capacity, he says. "There is currently 1.7 million metric tons per year of capacity for ethylene derivatives in Western Europe—300,000 could come off the market as uncompetitive." He argues that BP Chemicals has done its bit by backing out of ethylene glycol production at Lavéra, France, to focus on improving efficiency in oxide production at Antwerp, Belgium.

Ethylene derivatives are not the only petrochemicals with troubled futures. Another case in point is polyethylene. The industry already has abundant supply, with that situation expected to last until close to the end of the decade. However, Union Carbide and EniChem are joining forces to build new polyethylene plants in Europe (C&EN, Aug. 8, page 8). And the announcement of the Carbide-EniChem venture has been quickly followed by the decision of the board of directors of Denmark-based Borealis to complete construction of a new polyethylene plant at Porvoo, Finland.

The management at Finland's Neste and at Norway's Statoil, which have merged petrochemical operations into Borealis, originally planned to complete the plant this year. However, "the depressed market situation and overcapacity in the polyolefins industry prompted construction work to be postponed," Borealis officials point out now. Under the revised plan just approved, the plant is scheduled to begin operation in the fourth quarter of 1995, and it will have a capacity of 120,000 metric tons per year.

Patricia Layman

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CHEMISTS STEP UP SEARCH FOR HALON SUBSTITUTES PAGE 29

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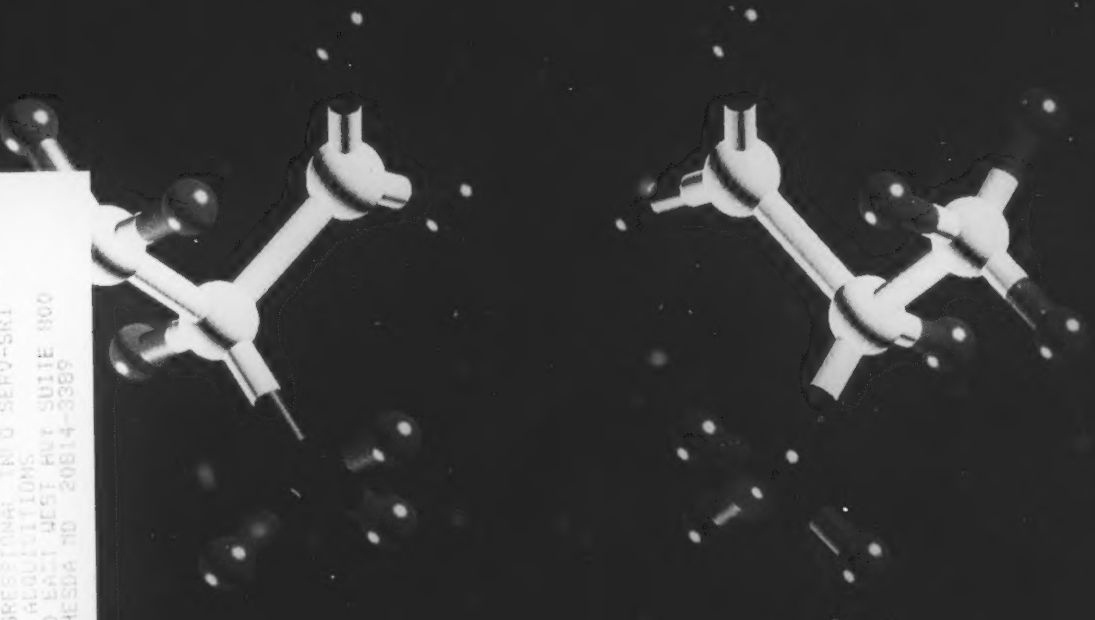

CHIRAL DRUGS

Single-isomer products drive development of new syntheses and separation techniques
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CHEMICAL & ENGINEERING NEWS

C&EN

SEPTEMBER 19, 1994

NEWS OF THE WEEK

- EPA's draft report on dioxins reaffirms that the compounds are a probable cause of cancer in humans and finds other health risks. Page 6
- Germany's Bayer buys key drug assets from SmithKline Beecham for $1 billion, regaining the right to use the Bayer name and logo in the U.S. Page 7
- Researchers in France have developed an all-organic transistor that may lead to low cost, large-area, flexible plastic electronic devices. Page 7
- Amgen and Corning are selected as corporate recipients of the 1994 National Medal of Technology. Page 8
- Union Carbide ends financial ties to India with sale of shares in Union Carbide India Ltd., owner of the closed Bhopal plant where a methyl isocyanate leak killed and injured thousands. Page 9
- Richard Mahoney, Monsanto's chairman and chief executive officer, will step down in March after 32 years with the company; Robert Shapiro has been named to succeed him. Page 9

COVER: Enantiomers of alanine modeled with Tripos' Sybyl software. Photo courtesy of Tripos

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BUSINESS

U.S. polypropylene producers face a challenging combination of increasing markets, production, and prices, and tight supplies of expensive feedstocks and shrinking exports. **Page 17**

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National Research Council panel proposes that federal and state agencies use a single approach in deciding priorities for toxic waste site cleanups. **Page 23**

Legislation will be introduced to regulate companies offering invention promotion and marketing services. **Page 25**

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Defense Department presses for suitable alternatives as deadline approaches for banning manufacture of halons now used in military applications. **Page 29**

FDA says genetically engineered tomatoes are not significantly altered compared with other tomatoes; studies show insecticidal protein expressed in tomatoes is nontoxic to mammals. **Page 32**

New antioxidant additive for melt processing of resins, introduced by Ciba, boasts of better properties. **Page 35**

ACS NEWS

Twenty-six local sections received Phoenix Awards in recognition of their efforts in carrying out projects for National Chemistry Week. *ƒ* Investigations of five multiple terminations detailed in a report by the Subcommittee on Professional Standards & Ethics. *ƒ* Undergraduate activities at national meeting include a graduate school fair. *ƒ* October local section meetings featuring ACS tour speakers. *ƒ* Corrections for 8th edition of "Reagent Chemicals: ACS Specifications." **Page 73**

CHIRAL DRUGS

A steady, rising flow of single-isomer forms of chiral drugs is increasing the worldwide demand for enantiomeric intermediates and bulk active compounds, as well as enantioselective technologies and services.
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Editor: Michael Heylin (202) 872-4501

Managing Editor: Madeleine Jacobs

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LETTERS

Don't blame immigration

A roundabout attempt was made in a letter by Kenneth Cohrs to attribute the unemployment trend of chemists to the Immigration Act of 1990, which increased the number of scientists and engineers admitted to the U.S. to 22,879 in 1992 from 14,100 in 1991 (C&EN, Aug. 22, page 5). However, there is a more direct answer to the question and possible solution to the problem.

The same issue reported that American Cyanamid and American Home Products have agreed to merge (page 7). Analysts have predicted that 10,000 jobs (about 13% of the combined work force) will be lost in this merger. In reality, the percentage of job loss during a merger was much higher in other reported cases. How many mergers have been completed in the chemical or manufacturing industries since 1991?

IBM alone has laid off more workers since 1990 than the total scientists and engineers allowed to immigrate to the U.S. It takes industrialists to create high-paying manufacturing jobs. DuPont, an immigrant, was one of them.

Chi-san Wu
Wayne, N.J.

ACS health plan

I am writing to encourage discussions among members and communication of their thoughts to their councilors regarding the formation of an ACS health care plan. Although ACS has tried several insurance plans in recent years, none of the non-life-insurance plans has the scope or impact that a health care plan would have for members.

The merits of such a plan are particularly strong for those of us working with companies undergoing consolidation (and the resultant layoffs), changing employers, working for employers who are unable to provide comprehensive benefits packages, recently unemployed, or self-employed.

The merits include stable health care plans for our families independent of our employers, continuity of coverage in the face of the fateful "preexisting condition" problem, participation in a very large group for economical rates, and not least, a very significant benefit associated with membership.

The problems of setting up such a plan are significant, including gaining corporate acceptance as another choice for employees where the company would contribute the same as it would to other offered plans. Given the large potential size of the group and the general good health of highly educated citizens, this plan may even be the plan of choice for small start-up companies, where many members are now employed.

I encourage you to initiate discussions exploring the feasibility of a members-only health plan. Now is the time to begin the informal discussions that lead to action.

Lee H. Latimer
Membership chairman,
ACS Philadelphia Section
Wayne, Pa.

Nonsense of proposals

As Pamela Zurer reports (C&EN, July 25, page 20), at least somebody at the National Institutes of Health has finally found enough common sense to raise the issue that we all know is long overdue. The battle, however, will not be easy because the very idea, "fund researchers, not proposals," is anathema for all the paper-shuffling bureaucracy and hence it is bound to face enormous logistical and political opposition.

Nevertheless, voices of dissent are growing. Nobel Prize physicist Leon Led-

Corrections

- July 25, page 24: Sepracor has an exclusive license on Jacobsen enantioselective catalysts for bulk quantities, but both Sepracor and Aldrich Chemical Co. are licensed to make, sell, and use research quantities of the catalysts.
- Aug. 15, page 16: The nylon fiber precursor plant in China's Liaoyang Province will have a capacity of 220 million lb per year, not 220,000 lb.
- Sept. 12, page 4: The National Medals of Science, which will be presented by President Clinton in October, are for 1994, not 1995.

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U.S. Polypropylene Producers Confront Troubling Supply-And-Demand Scenario

■ ***Rapidly growing demand, tight capacity, and raw material shortages test producers' ability to increase profit margins***

Ann M. Thayer,
C&EN Northeast News Bureau

Fina's polypropylene facility in La Porte, Tex., will be joined by a new plant in 1995.

To U.S. polypropylene producers, the waning days of summer are anything but. New capacity announcements, significant merger agreements, and booming end-use markets in the summer are being followed by early autumn price increases and even stronger demand growth.

But in an increasingly challenging market, events appear to be coming to a critical juncture. Tight raw material supplies, high costs for those feedstocks, and shrinking export markets make polypropylene a tough business in which to be profitable, despite production running at near maximum rates and rising prices.

Demand growth for polypropylene resins is expected to reach about 10% in 1994 and remain strong for the next few years, according to Houston-based consulting firm DeWitt & Co. "What we're seeing is positive economic growth virtually everywhere in the world and a market psychology that says plastics are going to be in shorter supply than they've been in the past," says Mark W. House, DeWitt's vice president for polymers. "Prices are going up ... and all of a sudden it becomes advantageous to buy all you can."

A relatively inexpensive and versatile material, polypropylene is used in a wide variety of products—automobiles, carpeting, diapers, medical equipment, rigid containers, and appliances. During 1994, about 9 billion lb of polypropylene are projected to be used in fiber, nonwoven, injection molding, and film applications. The Society of the Plastics Industry reported first-half 1994 polypropylene production at 4.64 billion lb, up 7.7% over first-half 1993, with sales and captive use up 10% to 4.91 billion lb.

However, polypropylene's growth—which is faster than that for most other resins, according to DeWitt—has not been driven by any particular end-use market area. Instead, overall U.S. market growth closely follows trends in gross domestic product growth and recent strong growth in all end-use areas. But as demand for polypropylene continues to increase, producers have been struggling to keep up. New production capacity is not expected to be in operation until late 1995.

The North American market for polypropylene is dominated by Himont, Amoco, Exxon, and Fina with a combined 55% of the 10 billion lb of nameplate capacity. Huntsman Chemical's pending acquisition of Eastman Chemical's polypropylene business, expected to close by Sept. 30, would place the company fifth among U.S. producers with an estimated capacity of more than 850 million lb.

Other producers are expected to strengthen their positions through capacity increases. Fina, an affiliate of the Belgium company Petrofina, announced in June that it would build a new 400 million-lb-per-year polypropylene facility at its plant in La Porte, Tex. Total polypropylene capacity at the site will be about 1.4 billion lb, making it the largest single polypropylene facility in the world when it is completed in late 1995.

Fina's La Porte plant will be the first of the new construction to go on-line. Formosa, delayed by licensing-related litigation with Phillips Petroleum, which holds a patent covering all U.S. polypropylene production, is expected to bring a 290 million-lb-per-year plant on-line this year at Point Comfort, Tex.

"At [current demand growth] rates, the industry needs two world-scale plants built a year," says H. Patrick Jack, Fina vice president for chemicals, who is concerned about the U.S. industry's ability to meet demand. The industry is already operating at a 93 to 95% capacity utilization rate, near maximum for polypropylene production because of technical limitations. "The industry is, in effect, running at all available capacity. There is just no more left," he adds. Even at the peak period for expansion, estimated by DeWitt to be 1996 and 1997, demand growth will still outpace capacity growth by about 2% per year.

Other construction announced is by Phillips Sumika Polypropylene, a 50-50 partnership between Phillips Petroleum and Sumika Polymers America, a unit of Sumitomo Chemical. In August, the partnership said it will add a new 270 million-lb-per-year plant at Phillips' Houston chemical complex to be completed in 1996. Also by 1996, Epsilon Products will double capacity, to 720 million lb, at its Marcus Hook, Pa., plant.

Another approximately 300 million lb of capacity is expected to be added between now and the end of 1995 through process improvements, says House. Aristech will increase capacity by 120 million lb per year at its Neal, W.Va., site. Seadrift Polypropylene, the Shell-Union Carbide joint venture, is expected to make gains of 35 million lb in early 1995 and another 65 million lb at the end of 1995 at its Texas plant. This year, Huntsman is increasing capacity by 40 million lb at its Woodbury, N.J., facility.

More expansions are anticipated in the next few years, especially since producers finally are achieving price increases under the tight supply-and-demand situation. Prices increased 3 cents per lb in March, another 3 cents in June, and again in September. Another increase is expected Oct. 1, which will bring prices up to more than 35 cents per lb.

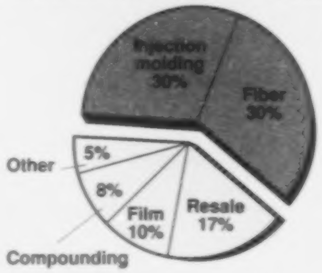
"There probably will not be any relief or plateau effect in polypropylene pricing rises until new production comes on-line in early 1996," says House. "That's the first drop in operating rates that I can foresee, so I expect supply and demand to be tight and pricing direction to be strong until that time." The strong pricing outlook is a significant change from the lack of price increases and profitability that has plagued polypropylene producers for the past few years.

In the late 1980s, following a period of price increases, capacity expansions in Latin America and Asia-Pacific resulted in a global market shift and an oversupply situation for U.S. markets. U.S. producers went from exporting about 21% of production in 1988 to about 6.6% today, according to DeWitt. The result was a tremendous drop in prices, back to mid-1970s levels, and extremely tight profit margins for several years.

John Hubby, general manager of Phillips Sumika, fears that a similar scenario could happen again. "A lot of [U.S. market growth] is being driven by low prices, quite honestly," he says. "So at some point, U.S. demand could get stalled out if prices go too high too quickly." Competition then could come from other plastics, which are also seeing price increases, or alternative materials such as glass, paper, and metal.

"The only consolation we've got is that the cycles appear to be lengthening out, [they are] not quite as abrupt as they may have been in the past. However, a concern is that the peaks may be there, but they may not last as long and the troughs last longer," adds Hubby.

Most polypropylene is used in molding and fiber



Total U.S. consumption of polypropylene[a] = 8.49 billion lb

a May 1993 through April 1994.
Source: DeWitt & Co.

U.S. polypropylene market led by few producers

Millions of lb	Capacity 1994	Capacity 1996[a]	% change 1994–96
Himont	1,918	2,006	5%
Amoco	1,660	1,660	0
Exxon	1,027	1,027	0
Fina	959	1,356	41
Aristech	721	985	37
Phillips Sumika	480	750	56
Eastman Chemical	441	441	0
Solvay	441	441	0
Huntsman	386	399	3
Epsilon	360	720	100
Shell	340	340	0
Quantum	300	300	0
Lyondell	300	300	0
Seadrift	198	298	50
Formosa	154	496	222
Rexene	150	150	0
Novacor	141	141	0
IGI Baychem	66	66	0
TOTAL	10,042	11,876	18%

a Includes as yet unannounced expansions.
Source: DeWitt & Co.

"The [trough] that we are just coming out of is the longest yet, and two or three years without making any money [makes] people begin to wonder whether it's the right business to be in at all."

Business planning and decision-making are more difficult under current market conditions, says Brad Jones, Huntsman's sales and marketing vice president for polypropylene. And other managers suggest that customers should be careful about their long-range planning and be sure of secure supply sources before going ahead with their own expansions. "We're very concerned about the ability of our customers to pass along the price increases," he says.

"Our customers are in a tenuous position right now. We are supplying them with data and market information ... so that they're able to communicate effectively to their customers why prices of polypropylene products are going up," says Jones. However, he does not have the same concern as Hubby about demand dropping due to high prices. "Polypropylene today is still less expensive than it was five years ago. In a relative sense, polypropylene continues to be one of the lower cost commodity products versus other polymers and alternative materials."

Profitability depends more on margins—the difference between selling prices and the combined costs of operating and raw materials—than on the ability to raise prices. Currently, rising propylene prices are contributing to increases in resin prices, but also continuing to seriously pinch margins. Three U.S. steam cracker outages—by Exxon, Shell, and Amoco—are severely affecting ethylene supplies and also are having an impact on propylene supply and pricing.

Hubby characterizes the raw material supply situation as "a little bit of a panic," whereas Fina's Jack calls it a crisis. "The raw material costs have already started going up, and that will continue through the end of the year and likely into the first quarter of next year," predicts Jack. "Polypropylene has just barely kept up with increases in raw material costs so far this year."

However, producers are optimistic that polypropylene margins will eventually improve above the few cents per pound they are seeing now. And they hope to see the capital needed for investing in new capacity. The picture has to get better, agrees Jones, "because if it doesn't, the shortage will be longer and harder." ☐

Chiral Drugs

New single-isomer products on the chiral drug market create demand for enantiomeric intermediates and enantioselective technologies

Stephen C. Stinson,
C&EN Northeast News Bureau

A number of trends characterize today's chiral drug industry. Perhaps the most important one is that a steady, rising flow of single-isomer forms of chiral drugs onto U.S. and world markets is creating an increasing demand for enantiomeric intermediates and bulk active compounds as well as enantioselective technology and services.

Another trend reflects the situation throughout the chemical industry—that of partnering. Specifically, in the chirotechnology industry of small and not so small firms that have grown up to serve drug companies, formal and informal alliances are being forged among firms that have different and complementary capabilities. And in asymmetric technologies, interest is unexpectedly surging in chromatographic separations as economically viable methods to make multiton quantities.

Meanwhile, in the coming age of managed health care, the big winners will be companies that make chiral drugs and seven-day adhesive plastic film skin patches formulated with single isomers of chiral drugs, according to Richard L. DiCicco, president of the consulting firm Technology Catalysts, Falls Church, Va. A number of factors back up DiCicco's prediction: Single enantiomers can be more selectively effective; skin patches contain much less drug and therefore can be less expensive to produce; and skin patches make patient compliance with drug regimens easier.

And DiCicco says that inventors of new, higher priced, patent-protected enantiomeric drugs can use them as bargaining chips with managed health care networks to maintain sales and prices of older, off-patent drugs. As an example of how this tactic works, DiCicco cites the marketing link by Ciba-Geigy in Switzerland of its off-patent anti-inflammatory drug diclofenac with its patent-protected transdermal nitroglycerin skin patches to treat angina (stress-induced chest pains of heart disease). DiCicco says Swiss purchasers get deep discounts on normally high-priced, patented skin patches if they also buy diclofenac at list price. DiCicco realizes that nitroglycerin itself is achiral. But he gives it as an example of marketing opportunities for chiral drugs.

DiCicco estimates the 1993 worldwide market for chiral drugs at $35.6 billion, a growth of 22% over 1992 alone. These figures are for shipments of dosage forms from producers' factories. DiCicco expects the market to grow at 5% per year to about $40 billion in 1997. But this is his conservative rate of growth. The estimate includes only growth of those compounds already approved by drug authorities worldwide, and not entries of agents that may be approved between now and 1997. Including these "to-be-approved" drugs, the 1997 chiral drug market could hit $60 billion, according to DiCicco.

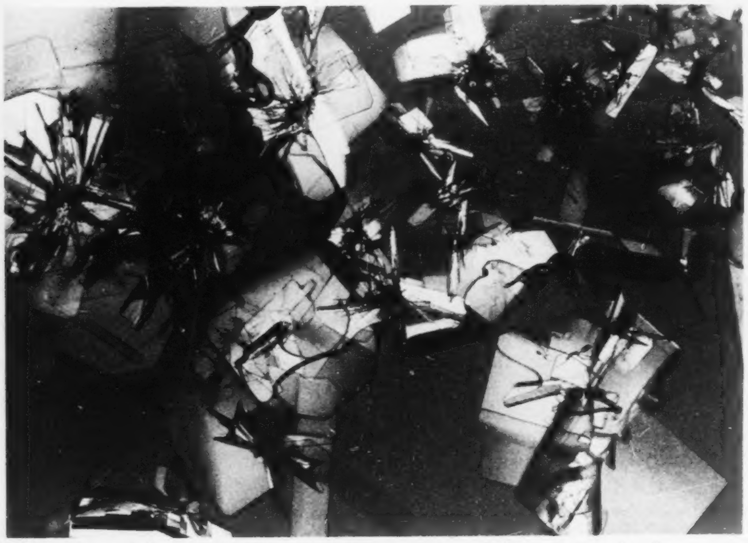
Sales of enantiopure drugs top $35 billion

$ Billion	1993 world sales[a]
Cardiovascular	11.3
Antibiotics	10.8
Hormones	4.5
Central nervous system	2.0
Anti-inflammatory	1.5
Anticancer	1.0
Other[b]	4.5
TOTAL	35.6

a Wholesale finished dosage forms. b Includes vitamins, amino acids, immunosuppressants, peptide drugs, antiglaucoma drugs, and plant extracts.
Source: Technology Catalysts

Such hedging as DiCicco's about whether to posit higher or lower estimates of the value of the chiral drug market comes from a new mood of uncertainty that has fallen over the drug industry. There has always been uncertainty as to the exact time when regulatory agencies would approve drugs that are new chemical entities. But now there is also uncertainty about whether and when agencies will approve single-isomer forms of drugs like ibuprofen that are already approved as racemates—the so-called racemic switches.

A lot of the projected growth of the chiral drug market rides on the success of racemic switches. For example, DuPont Merck Pharmaceutical Co., in Wilmington, Del., projects that the lysine salt of analgesic (*S*)-(+)-ibuprofen has the potential to be a $1 billion-per-year over-the-counter (OTC) drug. But the company has experienced long and unexpected delays while its new drug application (NDA) for the compound languishes at the Food & Drug Administration. And Sepracor, Marlborough, Mass., has assembled a stable of almost two dozen racemic drugs produced by other companies. Sepracor has redeveloped and patented the drugs in single-isomer forms and now seeks to license them.



Bifonazole crystals imaged with a polarizing microscope. Bifonazole is a chiral antifungal drug developed and marketed by Bayer.

In addition, some industry observers tell C&EN that there is mutual uncertainty among drug companies and FDA about policies to strive for in chiral drug approvals. For example, these industry observers say that approval for (*S*)-(+)-ibuprofen is slow in coming because FDA reviewers have not decided on a policy for dealing with racemic switches.

On the matter of how much of the "other" enantiomer FDA will allow in a drug, FDA spokesmen say the agency will balance synthetic convenience with the toxicity of the other enantiomer. Within the companies, some argue for approval of lower but adequate enantiomeric purities to make production within set specifications economically feasible. But others would like to push for ever higher enantiomeric purities in an effort to keep the qualities of their existing chiral drugs forever beyond the reach of generic competitors.

Although it is an example of purity of substance and not enantiomeric purity, DiCicco cites the immunosuppressant drug cyclosporin A marketed by Sandoz Pharmaceuticals Corp., East Hanover, N.J., as a case of how this latter tactic can work. The drug was originally approved with a specification of 97.5% purity. But in 1992, Sandoz filed what is called an in-process revision, setting a new purity specification of 98.5%. Generic drugmakers who want to market cyclosporin A must now find a source of 98.5% cyclosporin A and do their clinical equivalence testing on that.

The overall climate of uncertainty has led some to question whether the long-predicted boom in chiral drugs will actually happen. The question is whether the market will grow at only a moderate pace, limited by the number of new chemical entities in the pipeline, or whether the market will have the added fuel of numerous racemic switches.

Ton Wijsman, president of DSM Fine Chemicals, Saddle Brook, N.J., told an audience at Chiral USA '94 in Reston, Va., in May that the answer probably is slow market growth based on new chemical entities with little help from racemic switches. DSM is a large supplier of chiral drug intermediates, accounting for almost half of the $1.5 billion to $2 billion U.S. market, including intermediates for the cardiovascular drugs captopril and diltiazem; antibiotics amoxicillin, ampicillin, cefaclor, cefadroxil, and cefalexin; and the antiglaucoma drug timolol.

To make his point, Wijsman has added up the 95 best selling U.S. drugs based on drugstore sales. He notes that 36 single-isomer drugs on the list are new chemical entities that were approved between 1990 and 1993. Seven were approved in 1990, nine in 1991, 13 in 1992, and seven in 1993—an average of nine per year—indicating to Wijsman that there was no growth in numbers of single-isomer compounds during the four-year period.

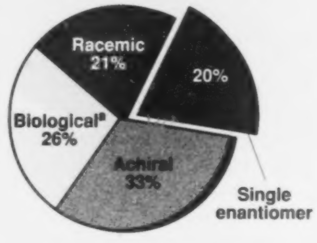
Wijsman also notes that the many expected racemic switches among β-adrenergic blocking agents to treat high blood pressure and heart disease have not materialized. And in addition to (*S*)-(+)-ibuprofen, several racemically switched "profens" (β-phenyl- and other β-arylpropionic acids) await U.S. approval, he says. Among the many already approved racemic drugs redeveloped as enantiomers by Sepracor, none has been approved and launched. Notably, Eli Lilly & Co., Indianapolis, shows no interest in licensing the (*S*)-fluoxetine isomer of its antidepressant drug Prozac.

By contrast, DiCicco argues that large-volume growth in chiral drugs is coming and hinges only on timing. He notes that G. Broschek Gebro of Tirol, Austria, has already launched (*S*)-(+)-ibuprofen in that country. And FDA has just approved marketing of the Aleve brand of the sodium salt of (*S*)-(+)-naproxen as an OTC analgesic drug by the joint-venture company Procter-Syntex Health Products, Cincinnati. This is not strictly a racemic switch, because the Anaprox brand of this enantiomeric compound had previously been approved and marketed as a prescription drug by Syntex Laboratories, Palo Alto, Calif. But DiCicco says this approval lights the way toward U.S. approval of (*S*)-(+)-ibuprofen and a host of other profens after that. As for delays or cancellations of racemic switches for β-adrenergic blockers, DiCicco says these compounds were rendered unnecessary by introductions of other enantiomeric drugs for heart disease—angiotensin-converting enzyme (ACE) inhibitors—into skin patches.

All of this activity in developing new chiral drugs has resulted in soaring demand for certain highly specialized intermediates. DiCicco cites enantiomers of glycidol (2,3-epoxypropanol), glycidyl triphenylmethyl ether, 2,3-isopropylideneglycerol (2,2-dimethyl-3-hydroxymethyldioxolane), and 3-aminoquinuclidine (3-amino-1-azabicyclo[2.2.2]octane) in particular.

Glycidol is an intermediate on the way to several interesting compound classes. DiCicco estimates world demand at 10,000 kg yearly, of which 5,000 kg alone is for research. The major source for the alcohol has been Daiso Co. of Osaka, which has dropped out of

Single enantiomers are 20% of best selling drugs



Total number of drugs = 95

Note: Figures are for 95 best selling drugs according to U.S. drugstore sales, excluding hospitals and international sales. [a] Sources are biotechnology, fermentation, and extraction. **Source:** DSM Fine Chemicals

supplying it in favor of producing more profitable glycidyl derivatives.

The upsurge in demand for the triphenylmethyl (trityl) ether may result from the ease with which this group comes off after reaction of the epoxy group. And 2,3-isopropylideneglycerol is seen as a replacement for glycidol. Substituted benzamides of 3-aminoquinuclidine are in tests as next-generation antipsychotic drugs. They act by binding to brain nerve cell receptors of the neurotransmitter 5-hydroxytryptamine (serotonin) of a type called 5-HT$_3$.

Chiral separation techniques

Activity to develop chiral drugs has also led to progress in manufacturing them and their enantiomeric precursors. A recent surprise is the emergence of liquid chromatographic methods from relative disfavor to become highly promising ton-scale processes.

One reason for the former disfavor is that any separation of enantiomers from a racemate results in the waste of the unwanted enantiomer, a waste of 50% of the material. Only the possibility of finding a use for the "other" isomer or of racemizing the unwanted enantiomer and recycling it through the separation process can improve the cost-effectiveness of this situation. Furthermore, cost is a reason for disfavor since liquid chromatography uses large quantities of solvents.

But sometimes the asymmetric synthetic route to a drug or intermediate is so difficult that separation of a racemate turns out to be the cost-effective solution. Verapamil is one such case. The racemate has long been approved as a calcium channel blocker to treat high blood pressure, angina, and abnormal heart rhythms. The (*S*)-isomer alleviates high blood pressure even more effectively than the racemate, while the (*R*)-form is now found to inhibit resistance of cancer cells to anticancer drugs.

As in other parts of the chirotechnology industry, enantioselective liquid chromatography is a mosaic of alliances between firms with complementary technologies and ties to inventive academic chemists. In the matter of enantioselective column packings, for example, Tokyo-based Daicel Chemical Industries has teamed with chemistry professor Yoshio Okamoto of Nagoya University. Daicel's U.S. subsidiary is Chiral Technologies, Exton, Pa.

Daicel-Okamoto packings depend on cellulose backbones to impart the chiral environment. To make Chiralcel OD, for example, Daicel reacts cellulose with phosgene to attach up to three pendant chloroformate ester groups to each glucose unit. Reaction next with 3,5-xylidine forms 3,5-dimethylphenylcarbamate groups, which give the packing the appropriate affinity to separate enantiomers of aromatic, carbonyl, cyano, hydroxy, nitro, and/or sulfonyl compounds.

Regis Technologies, Morton Grove, Ill., has commercialized enantioselective packings invented by organic chemistry professor William H. Pirkle of the University of Illinois, Urbana-Champaign. Pirkle columns feature enantiomeric compounds called chiral selectors that are covalently bound to silica gel. Pirkle designs each chiral selector to provide three different types of noncovalent binding to racemate molecules.

For example, the packings that Regis offers under the names (*R,R*) or (*S,S*) Whelk O1 contain a naphthalene nucleus and a 3,5-dinitrobenzamide group. The naphthalene interacts with racemate molecules by π-electron donation, the dinitrophenyl by π-electron acceptance, and the amide group by hydrogen bonding. Pirkle justifies three as the number of binding interactions needed because the chiral selector must recognize the front and back, top and bottom, and both sides of each molecule coming past.

Advanced Separation Technologies, Whippany, N.J., continues to bring out packings developed by analytical chemistry professor Daniel W. Armstrong of the University of Missouri, Rolla. Armstrong's most recent products, which Advanced Separation will introduce this fall, are based on the macrocyclic antibiotics rifamycin B and vancomycin as chiral selectors linked to silica gel. Armstrong depends on the complexity of these molecules to offer several different binding interactions at once: π-π complexation, hydrogen bonding, inclusion in a hydrophobic pocket, dipole interactions, and/or steric repulsion.

The obvious application of all these packings is conventional column liquid chromatography for analysis or production. But Daicel/Chiral Technologies and Sepracor, which also specializes in chiral separations, are seeking partners to use such packings in what is called simulated moving bed chromatography.

Directory locates sources of chiral compounds

For anyone looking for sources of enantiomeric compounds for production of chiral drugs, "The R-S Directory," 2nd edition, is an 89-page, spiral-bound compilation of more than 1,000 enantiomeric intermediates, auxiliary reagents, and resolving agents produced by more than 50 companies. The directory is indexed by compound name, molecular formula, and producer name. It supplies addresses as well as telephone, fax, and telex numbers of producers, including those of branch offices and subsidiaries of foreign firms in the U.S. and/or Europe.

The directory does not list such common, naturally occurring compounds as terpenes, L-amino acids, or even protected amino acids. However, other chemical derivatives of such natural products are included. Also not listed are laboratory chemical supply houses. Thus Sigma Aldrich, a laboratory chemical supply house that is also a basic producer of chiral compounds, is a notable omission. The booklet can be purchased for $115 by ordering from The R-S Directory, P.O. Box 153, Purley, Surrey CR8 5YN, England.

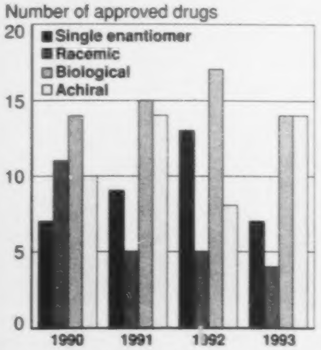
Though an awkward description, "simulated moving bed" has 30 years of engineering tradition behind it in petrochemical and food processing, so it is certain to find wide use in the chirotechnology industry. The idea is that in normal chromatography the liquid carries the sample forward through a stationary bed of packing. If the column length is sufficient, the components in the sample become separated according to their relative affinities for the packing material.

Simulated moving bed refers to a technique that behaves as if the packing were moving backward at the same time. If that were possible, the column could be shorter. In the actual process, the bed of packing does not move. Rather, the front and back ends of the column are joined to form a circle. And the operator moves the points of injection of fresh sample, injection of fresh solvent, and removal of components of the mixture around the circle.

To use an analogy, the process is like the sequential turning on and off of light bulbs on a theater marquee. The pattern of lights appears to move around the marquee, although the light bulbs themselves do not move.

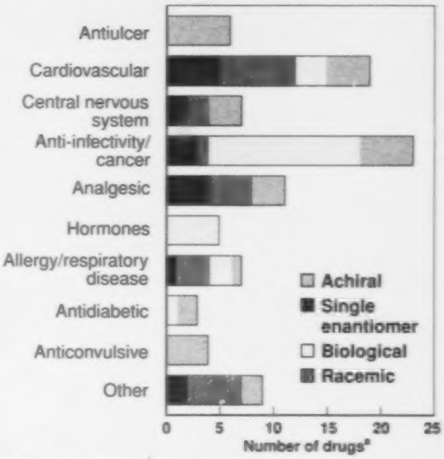
To resolve a racemate, the operator injects a bolus of the racemate into the circular column, where the solvent is already being pumped along. After a time, the bolus moves part way around the circle and separates incompletely into two peaks. The moving front contains one pure enantiomer, and the tail contains the other. Calculating where the bolus is in the circle, the operator withdraws portions from the front and tail as products, injects new racemate into the center of the bolus, and replenishes the solvent with an injection at a part of the circle away from the moving bolus. After a time sufficient for new partial separation, the operator repeats the sequence of injections and withdrawals at the appropriate parts of the circle.

Biological products lead drug market growth



Source: DSM Fine Chemicals

Proportion of chiral drugs sold varies with therapeutic class



[a] Best selling drugs according to drugstore sales.
Source: DSM Fine Chemicals

Mark J. Gattuso, business development manager at UOP, Des Plaines, Ill., says UOP received its first patents on its Sorbex simulated moving bed technology in the 1960s. UOP is cooperating with Chiral Technologies to apply the process to resolution of racemates, though no formal agreement has been reached between the two companies.

Speaking at the Chiral Europe '94 conference this month in Nice, France, Gattuso said that among the company's two dozen versions of the process applied to petrochemical, food, and drug separations, UOP has licensed 53 plants to separate *p*-xylene from C_8 aromatics, 33 to separate *n*-paraffins from branched and cyclic hydrocarbons, six to separate olefins from paraffins, five to separate fructose from corn syrup, and one to purify citric acid. His point is that, after 30 years of such successes, a simulated moving bed approach will also work in enantioselective separations. As to economics, Gattuso says process costs are less than 10 cents per kg at a 100,000-metric-ton-per-year plant and 15 cents at 15,000 metric tons per year.

Besides the informal cooperation between Chiral Technologies and UOP, Sepracor has a similar loose alliance with Separex Chimie Fine of Champigneulles, France. Separex offers two units, the Licosep $^{12}/_{26}$, which is capable of separating 10 to 400 g of racemate per 24-hour day, and the Licosep $^{8}/_{200}$, with a capacity of 500 g to 25 kg per 24-hour day. The two systems have 12 "small" or eight "large" chromatographic columns, respectively, in a loop. At each junction of the columns are four valves to accommodate injections of racemate and solvent and withdrawal of products. A microcomputer uses Separex software to operate the valves in sequence.

The French company recently resolved the drug intermediate 2,3-epoxy-5-methoxytetralin under a contract with Sandoz of Basel, Switzerland, using methanol solvent and cellulose triacetate column packing. The yield of desired enantiomer was 100%, based on its total content in the racemate, compared with 70% by conventional chromatography. Consumption of methanol was 320 g per gram of racemate compared with 2.4 kg for conventional chromatography. The economy of solvent consumption results from the 15 times greater concentration of racemate that is possible in this cyclic process than in conventional liquid chromatography.

Separex president Roger-Marc Nicoud estimates that costs of simulated moving bed resolutions of racemates might be \$100 to \$1,000 per kg on a scale of 500 kg per year. This cost range is much higher than for xylenes or fructose because economies of scale are lacking and labor costs are a larger proportion of the total on the small scales involved.

Aside from developments in simulated moving beds, Akzo Nobel International Research, in Arnhem, the Netherlands, has developed an enantioselective countercurrent extraction technique capable of scaling up to ton quantities. Marketing manager Mirjam S. Leloux described the process at the

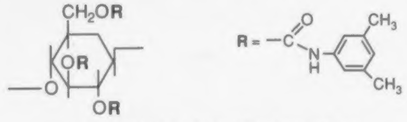
Chiral USA '94 conference in Reston.

In one experiment, two heptane solutions in a cell flow parallel to one another, in opposite directions, separated by a membrane. The membrane is water-saturated cellulose. One heptane solution is 10% in dihexyl D-tartrate and the other is 10% in dihexyl L-tartrate. Racemic norephedrine (2-amino-1-phenyl-1-propanol), a decongestant drug, is added to one of the solutions.

Heptane solvent and dihexyl tartrate solutes are hydrophobic and cannot cross the water-saturated membrane. The fairly polar aminoalcohol norephedrine crosses the membrane back and forth. As liquid flow continues, each enantiomer of norephedrine is concentrated on the side of the membrane containing the tartrate enantiomer with which it has the greater affinity.

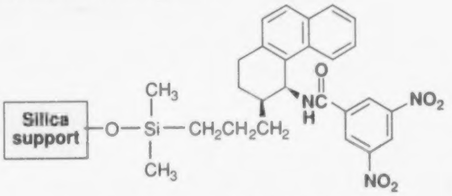
Enantioselective column packings vary in molecular design

Daicel packings are cellulose based



Chiralcel OD, Chiral Technologies

Pirkle packings derive selectivity from threefold bonding sites



(*S,S*) Whelk-O1 CSP, Regis Technologies

■ Electron donor group ■ Electron acceptor group
■ Hydrogen-bonding group

In the laboratory, Akzo Nobel chemists use commercial dialysis cells in which the membrane is a narrow tube passing concentrically through a larger shell. One solution flows through the tube, the other outside through the shell. Akzo Nobel workers connect as many cells in series as are needed to obtain separation. In addition to dihexyl tartrates, other possible hydrophobic chiral selectors include O,O-dibenzoyltartaric acids, polylactic acids, dimethyl 2,3-isopropylidenetartrates, and fenchones.

Leloux points out that a small apparatus can separate several grams of drug for toxicity and preclinical testing, and later the process can be scaled up to produce commercial amounts. This use of the same method throughout will simplify the process of satisfying regulatory requirements, she says. Akzo Nobel seeks to license the technology to drug company users.

Chromatography analyses

In addition to its new promise as a production process, liquid chromatography has become the drug industry's method of choice to determine enantiomeric purity. Classical optical rotation has been dismissed because of unreliable dependencies on temperature, solvents, and concentrations. And nuclear magnetic resonance spectrometers are costly to tie up routinely.

In the matter of chiral drug analysis, chemistry professor Christian Roussel of the University of Aix in Marseilles, France, has assembled a database of liquid chromatographic chiral separations to aid chemists in fast pinpointing of detailed analytical methods that work. Roussel notes that there are basically two types of chiral column packings. One is the Pirkle or Armstrong type with an enantiomeric chiral selector bound to an achiral substrate such as silica. The second is a chiral polymer like a polysaccharide (as in the Daicel approach), protein, or synthetic resin made from an enantiomeric monomer or by chiral polymerization. Of the 560 packings cataloged in his Chirbase, about half are silica based and half are chiral macromolecular. Among the 560 packings, 110 are commercially available.

The database includes descriptions of 24,000 individual analytical separations, and Roussel and his coworkers add to these at the rate of 4,000 per year. And 8,000 structures of compound's enantiomers have been chromatographically separated and are archived. Database searches are molecular-structure oriented. Users can enter their own data into their copies of Chirbase.

The Chirbase client either uses an IBM 386-compatible computer on a local version called ISISBase or accesses the database via Ethernet on a VAX minicomputer in Marseilles, which offers even more versatile software and search techniques. One search type is for an exact structure match. Widening the search, the user may stipulate that isomers, tautomers, or parent compounds of the target molecule are allowed. A second search type is by substructure, in which the user sequentially builds an "R-group" based on structural features of the analyte target molecule and responses from the database. A third search is by similarity, in which the user is guided to estimate a percent similarity that is permitted. The program then furnishes chromatographic conditions that have succeeded on compounds in that range of similarity.

Whether chromatographic or other, drug companies will usually have to develop enantioselective analyses for both single isomers and racemates of chiral drugs. Jeffrey J. Blumenstein of

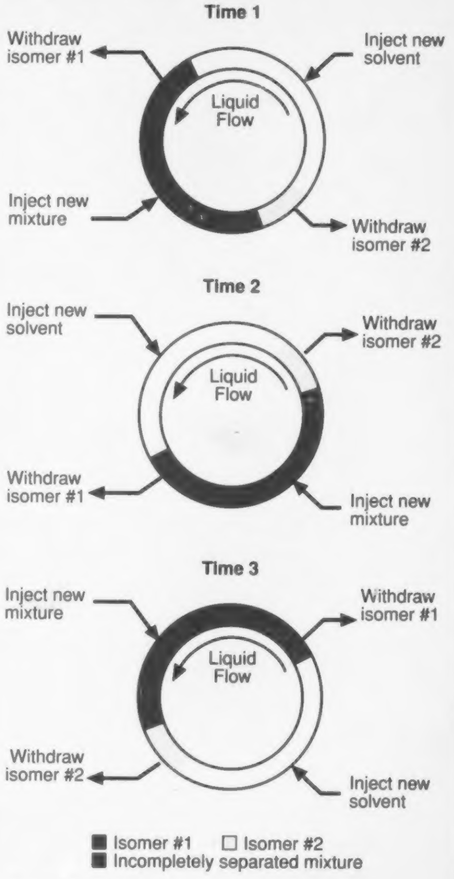
Worker at Chiral Technologies monitors high-performance chromatographic separation of enantiomers in 10- × 50-cm column capable of processing up to 1-kg samples.

FDA's Office of Drug Evaluation says that such analyses may have to be done on both the bulk active substance, the dosage form of the drug, and any key intermediates. And such analyses should include tests of identity and assays of how much drug and how much of a single isomer is in a sample.

Among drugs generally, there are many criteria to decide whether a starting material or intermediate is "key." But as to chiral drugs, Blumenstein says any synthetic step that introduces an asymmetric center renders that product as key. And subsequent reactions and their products that have the potential to change the configuration at the asymmetric center will also bring the requirement for enantioselective testing of those products.

But Blumenstein also says that intermediates and some drugs with multiple stereogenic centers may not need stereoselective analyses. This is because it is unlikely that both asymmetric atoms of a molecule with two such atoms will undergo a change to the opposite configuration at once. Therefore, if only one atom changes, the result is a diastereoisomer and not an enantiomer of the changed compound. And presence of diastereoisomers can be detected by achiral methods.

Cycling sequence makes column seem to 'move backwards'


Time 1
Withdraw isomer #1
Inject new solvent
Liquid Flow
Inject new mixture
Withdraw isomer #2
Time 2
Inject new solvent
Withdraw isomer #2
Liquid Flow
Withdraw isomer #1
Inject new mixture
Time 3
Inject new mixture
Withdraw isomer #1
Liquid Flow
Withdraw isomer #2
Inject new solvent
■ Isomer #1 ☐ Isomer #2
■ Incompletely separated mixture

Source: UDP

1. After each injection of fresh mixture, the flow of liquid begins some separation of components.

2. At the appropriate moment, a sample of enriched component is drawn off as product.

3. Valves placed at strategic locations around the looped column allow the operator to time injections and withdrawals.

Nonlinear enantioselective effects

Just as the emergence of simulated moving bed techniques has changed the fortunes of liquid chromatography in drug production, so, too, a new awareness of nonlinear effects has changed the landscape of asymmetric synthesis in general. Among these nonlinear effects is one called asymmetric amplification. This means that use of a catalyst or reagent with low enantiomeric purity may yield a product of higher enantiomeric purity.

The question of asymmetric amplification has become a factor in the patent position of Aldrich Chemical, based in Milwaukee, with respect to enantiomeric organoboranes. In 1987, organic chemistry professor Herbert C. Brown of Purdue University developed and patented both enantiomers of diisopinocampheylchloroborane as asymmet-

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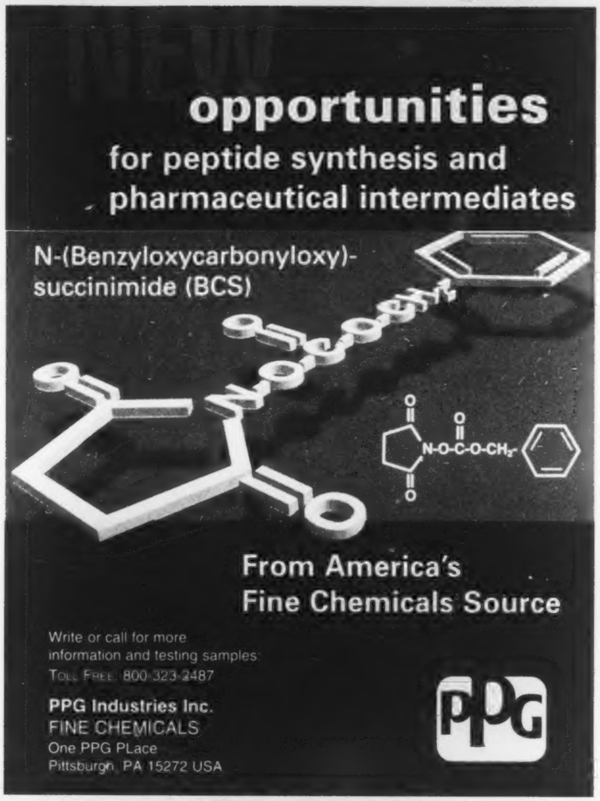

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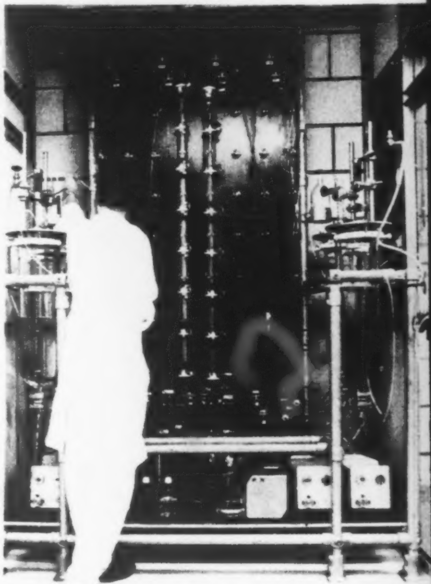

Researcher at Akzo Nobel International Research checks behavior of the company's proprietary countercurrent extraction columns for separation of enantiomers from racemates.

ric reducing agents of ketones to secondary alcohols. Despite the forbidding name, these reagents are conveniently available from diborane and either enantiomer of α-pinene.

Aldrich Chemical has a license on the Purdue patents and markets the reagents under the tradename DIP Chloride. In particular, one patent describes the production of DIP Chloride, and another covers its use in greater than 95% enantiomeric excess to produce secondary alcohols in similarly high enantiomeric excesses. Organochloroborane of this high enantiomeric excess is hard to make, because the air- and moisture-sensitive compound must be laboriously crystallized after synthesis from pinenes from natural sources of lesser enantiomeric purities.

Meanwhile, Callery Chemical, Evans City, Pa., has invented an alternative route to produce diisopinocampheylchloroborane. And developments at Merck & Co., Rahway N.J., may have shot away the protection of Aldrich's high-enantiomeric-excess patent. In 1991, medicinal chemists at Merck reported that reagent made with α-pinene of only 70% enantiomeric excess reduced a ketone to a secondary

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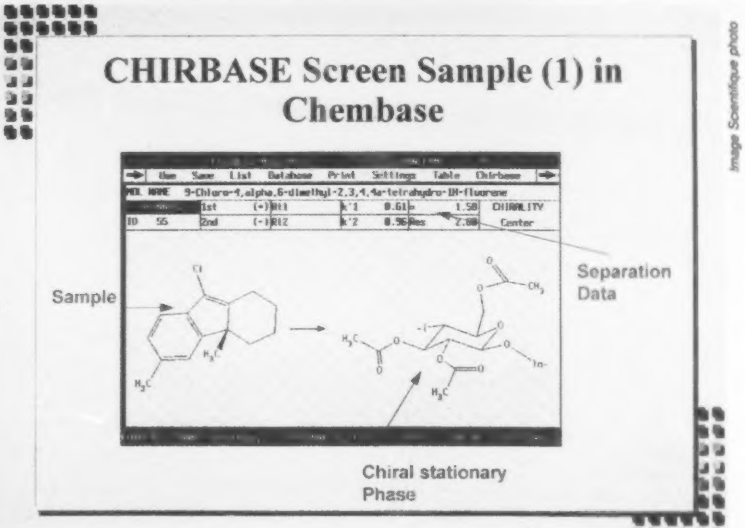
CHIRBASE Screen Sample (1) in Chembase

MOL NAME 9-Chloro-4,alpha,6-dimethyl-2,3,4,4a-tetrahydro-1H-fluorene

ID 55

1st (+) Rt1 k'1 0.61 α 1.58

2nd (-) Rt2 k'2 0.96 Res 2.80

Computer screen display during a search for optimum liquid chromatographic separation conditions on Chirbase, developed at the University of Aix, Marseilles, France. The structure at left is the compound analyzed and the structure at right is the chiral column packing used. Also given are the literature reference and exact conditions.

Image Scientifique photo

alcohol in greater than 98% enantiomeric excess. The implication is that unanticipated asymmetric amplification makes pinenes of high enantiomeric purity unnecessary. Nevertheless, Callery is going ahead with negotiating an agreement with Aldrich to gain access to organoborane technology at all levels of enantiomeric purity.

Organic chemistry professor Henri B. Kagan of the University of Paris-South, in Orsay, France, has contributed a great deal to the understanding of asymmetric amplification and other chiral nonlinear effects. He described his newest results at the chiral conference in Nice. His most surprising finding is that catalysts and reagents may exist that give worse enantiomeric purities when they themselves are enantiomerically pure than when those agents are less than enantiomerically pure.

As an example, most chiral catalysts and reagents have two or more molecules of enantiomeric ligand, L, bound to a metal, M. In the Aldrich and Callery boranes, boron is the "metal."

If the ligands are enantiomerically pure, then the catalyst or reagent is either all $M(L_R)_2$ or $M(L_S)_2$. But if a ligand that is nominally L_R is present in only 50% enantiomeric excess, then there are just three molecules of L_R in the mixture for every one of L_S. So the catalyst or reagent is on average a 50-50 mixture of $M(L_R)_2$ and ML_RL_S.

If $M(L_R)_2$ is an active agent, and if ML_RL_S is relatively inactive, then the enantiomeric purity of the reaction product will be decided by L_R to an ex-

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tent greater than its presence in the catalyst or reagent. The effect of L_R is amplified. A graph of enantiomeric purity of product versus catalyst or reagent will be curved, not linear.

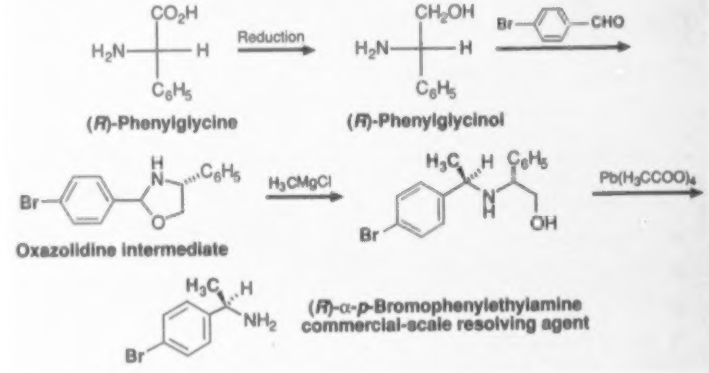
Kagan has also done the mathematics for an agent that is ML_4. In this case, there is a possibility that the graph of enantiomeric purity of product versus that of agent will be doubly curved. Thus an enantiomerically pure catalyst or reagent could theoretically give worse results than a less pure one. No such case has yet been observed, and the mathematics may be academic. But events of the past few years have changed nonlinear chiral effects from academic curiosities to important factors in drug research and patent law.

A recent on-purpose design of what might be called an asymmetric amplification is "chiral poisoning" of a cheap racemic hydrogenation catalyst in order to avoid use of a costly enantiomeric catalyst [*J. Am. Chem. Soc.*, **115**, 804 (1993)]. Organic chemistry professor John W. Faller of Yale University starts with racemic 2,3-bis(diphenylphosphino)butane, which is nicknamed chiraphos. He complexes chiraphos with rhodium to make the catalyst. Then he adds half an equivalent of a diphenylphosphino derivative of L-methionine.

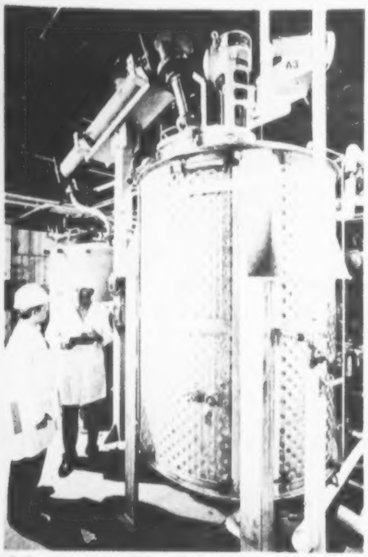
The chirality of enantiomeric methionine causes it to complex preferentially with one enantiomer of racemic chiraphos-rhodium catalyst. The sulfur of methionine poisons the catalytic activity of the chiraphos-rhodium enantiomer with which it reacts. The low cost of methionine makes the enantiomeric poison cheap compared with enantiomeric chiraphos-rhodium. In a demonstration of the chirally poisoned catalyst system, Faller uses it to reduce α-methylenesuccinic (itaconic) acid to α-methylsuccinic acid in 49% enantiomeric excess.

Continued on page 57

'Chiral pool' furnishes amino acids for chemical syntheses



Source: SmithKline Beecham Pharmaceuticals



Celgene's new 700-gal reactor at Warren, N.J., exemplifies growing recognition by chirotechnology companies that they need synthetic chemical as well as biotechnological capabilities.

Asymmetric syntheses

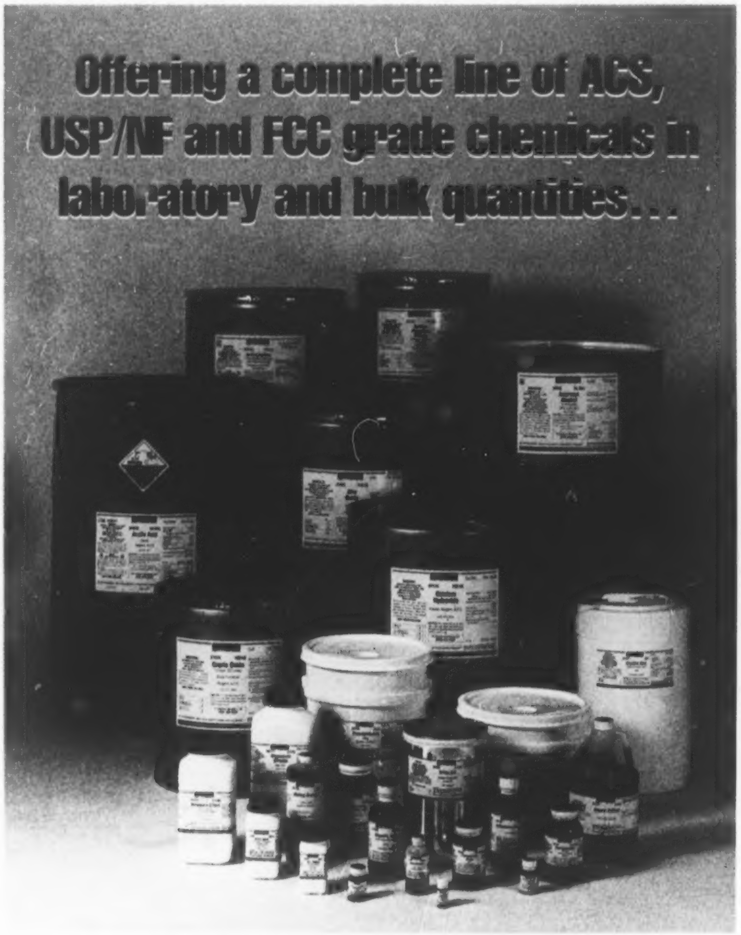
Theoretical and practical work show how much progress has been made in asymmetric reduction of ketones to enantiomeric secondary alcohols. But chemist Hans-Ulrich Blaser of Ciba in Switzerland says similar progress is lacking in the all-important problem of reducing imines ($R_2C{=}N$-R) to enantiomeric amines. Amines are important in medicinal chemistry.

Blaser explained at Chiral Europe '94 in Nice that imine Schiff bases form readily from amines and carbonyl compounds. But reactions are often incomplete, and trimers and other longer congeners also generally form. Schiff bases are additionally unstable to hydrolysis. And there is the problem of geometric syn-anti isomerism about the C=N bond.

The asymmetric hydrogenation catalysts now available are not very active toward imines and need high temperatures and pressures to succeed. But Blaser says that hydrogenation is still the best bet. This is because hydrogenation leaves no reagents to recover and no boron or aluminum wastes to dispose of. Blaser is optimistic that hydrogenation catalysts will allow imine production to approach that of secondary alcohols. There are increasing numbers of enantiomeric diphosphine ligands becoming available, he says, and experiments on their chelates with iridium, rhodium, and ruthenium may lead to the needed activity.

Another tactic in asymmetric synthesis is use of chiral synthons. These synthons are enantiomeric compounds that serve as starting materials and whose own chirality induces the desired chirality during the reactions that follow. One recent application is that of chemist Lendon N. Pridgen of SmithKline Beecham Pharmaceuticals in King of Prussia, Pa.

As Pridgen explained in Nice, his synthetic chemistry department received an internal request for large amounts of (*R*)-α-*p*-bromophenylethylamine as a resolving agent to separate a racemic carboxylic acid in production of a single-isomer drug. Pridgen's solution was to use the chirality of (*R*)-phenylglycinol, which was also to provide the amino group. Treatment of that with *p*-bromo-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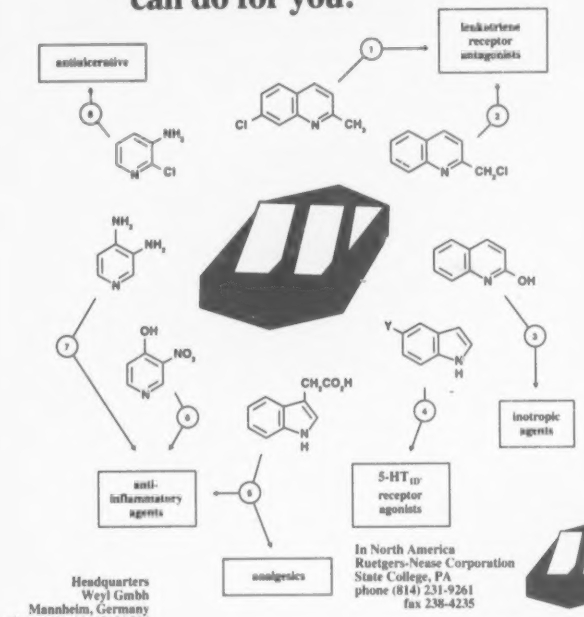

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Exploring a world of mirror images

"Now if you'll only attend, Kitty, and not talk so much, I'll tell you all my ideas about Looking-glass House. First, there's the room you can see through the glass—that's just the same as our drawing-room, only the things go the other way.... Well then, the books are something like our books, only the words go the wrong way: I know *that*, because I've held up one of our books to the glass, and then they hold up one in the other room.

"How would you like to live in Looking-glass House, Kitty? I wonder if they'd give you milk in there? Perhaps Looking-glass milk isn't good to drink."

—Lewis Carroll, "Through the Looking-Glass," 1871

benzaldehyde yielded an enantiomeric oxazolidine, which now also contained the needed *p*-bromophenyl group. Reaction with methylmagnesium chloride added a methyl group, and oxidation with lead tetraacetate freed up the phenylethylamine product.

Process research manager David Tapolczay of Glaxo Research & Development, Greenford, England, also described the chiral synthon approach at Chiral Europe '94 in searching for ways to make cyclopentane aminoalcohols. Such aminoalcohols mimic ribose and deoxyribose in antiviral drugs. The particular target was a single enantiomer of a 4-amino-2-hydroxymethylcyclopentanol.

Tapolczay turned to a popular starting material known as Vince's lactam (2-azabicyclo[2.2.1]hept-5-en-3-one). He worked out routes to the desired cyclopentane derivative beginning with racemic or enantiomeric lactam and proceeding by way of single-isomer methyl 4-benzamino-2-cyclopentenecarboxylate. Two other firms active in enantiomers of both Vince's lactam and the carboxylate are Chiroscience, Cambridge, England, and Lonza of Basel, Switzerland, and Fair Lawn, N.J. So Glaxo is also able to buy intermediates from them.

While Pridgen and Tapolczay cite use of chiral synthons to solve individual problems, organic chemistry professor Dieter Enders of the Rhine-

Westphalia Institute of Technology, Aachen, Germany, has created a whole cottage industry out of chiral auxiliaries that he calls SAMP-RAMP. Chiral auxiliaries are enantiomeric compounds that are temporarily attached covalently to a substrate. The auxiliaries induce desired chirality during later reactions on the substrate. Finally, the auxiliaries are cleaved and, chemists hope, recovered. SAMP and RAMP are (*S*)- and (*R*)-1-amino-2-methoxymethylpyrrolidines.

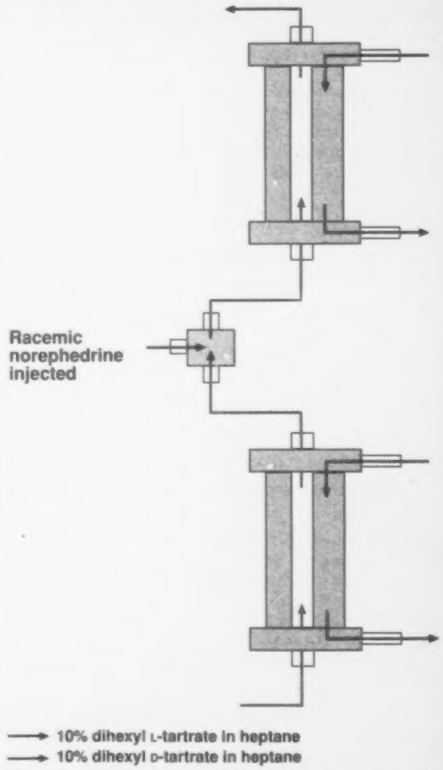
Because these auxiliaries are hydrazines, one reaction they undergo is formation of hydrazones with ketones. The hydrazone function sets up the rest of the molecule for further reactions, and the chirality of the pyrrolidine induces the desired chirality in the reacting substrate at the same time. The hydrazones can be cleaved at the end of the reaction sequence.

One of Enders' examples in Nice was the synthesis of so-called (*S*,*S*)-A-74,704, a human immunodeficiency virus (HIV) protease inhibitor that is a candidate drug for treating AIDS. The starting material is the acetonide of dihydroxyacetone (2,2-dimethyl-1,3-dioxolan-5-one). Enders uses SAMP to form a hydrazone, then a combination of butyllithium and benzyl chloride to introduce a benzyl group adjacent to each side of the C=N bond forming two new asymmetric carbon atoms in the desired configurations. Later in the sequence, the SAMP hydrazone is converted back to the ketone, which is reduced to a hydroxyl group that occurs in the final drug product.

Both SAMP and RAMP are now commercially available from Oxford Asymmetry, Abingdon, England, which offers chiral auxiliaries developed by many academic chemists worldwide. Oxford Asymmetry was originally founded by organic chemistry professor Stephen G. Davies of nearby Oxford University, with funding from outside investors, in order to commercialize his own compounds.

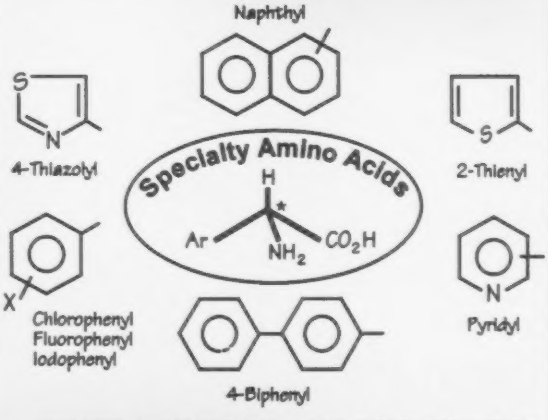
Indeed, the newest products from Oxford Asymmetry are Davies' own enantiomeric 5-methoxymethyl, 5-ethoxymethyl-, 5-trityloxymethyl-, and 5-*tert*-butyldimethylsilyloxymethyl-3,3-dimethyl-2-pyrrolidones, made from L-glutamic acid. These compounds are

Countercurrent extraction separates drug or intermediate enantiomers


Racemic norephedrine injected
10% dihexyl L-tartrate in heptane
10% dihexyl D-tartrate in heptane

1. Heptane solutions of tartrate esters are separated by water-saturated cellulose membranes.
2. Polar norephedrine molecules can pass through membranes back and forth between D- and L-tartrate compartments, but tartrate ester molecules cannot pass the membranes.
3. At equilibrium, almost all of one norephedrine enantiomer is complexed with one tartrate ester in one compartment, while most of the other norephedrine enantiomer is in the other compartment.

Source: Akzo Nobel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designed to bond to substrates at the pyrrolidine nitrogen, induce the desired chirality in the substrate during subsequent reaction, and then be easily hydrolyzed.

Biotransformations in syntheses

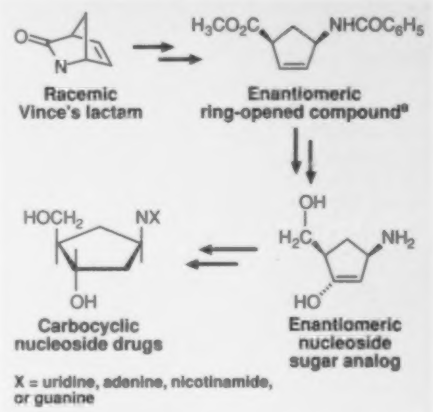
In addition to synthetic organic chemical approaches to asymmetric syntheses and resolutions of racemates, biotransformations have become key technologies, with many firms serving the drug industry. Many startup firms that began with biotransformations have found it necessary to add synthetic chemical capabilities.

Lonza is the newest company to add biotransformations to its existing synthetic organic technologies. The firm has acquired a fermentation plant in Kouřim in the Czech Republic. Biotechnology manager Olwen M. Birch described at the Nice conference how Lonza coordinates its chemical production in Visp, Switzerland, with the new biotechnological capabilities in Kouřim.

One such project is production of cilastatin, a drug originally discovered by Merck to prolong the lifetime of β-lactam antibiotics in the body. Cilastatin is an N-substituted (S)-2,2-dimethylcyclopropanecarboxamide. Several chemical routes to the compound are possible, beginning with the synthesis of racemic 2,2-dimethylcyclopropanecarbonitrile from readily available starting materials.

Switching to biotransformations, Lonza uses a nonstereoselective nitrile hydratase to catalyze conversion of the nitrile to racemic amide, and an amidase to hydrolyze the (R)-amide preferentially to the (R)-carboxylic acid, leaving the desired (S)-amide for cilastatin production. Switching back to chemistry, Lonza reacts the (R)-acid first with thionyl chloride, then with ammonia, to get back to the racemic amide. This recovered racemic amide is combined with more racemic amide from hydrolysis of nitrile, thus enabling a theoretical 100% conversion of starting material to the (S)-amide.

Glaxo synthetic route leads to aminoalcohol nucleoside analogs



X = uridine, adenine, nicotinamide, or guanine

a Also available commerically from Lonza.
Source: Glaxo Research & Development

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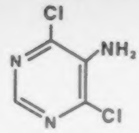
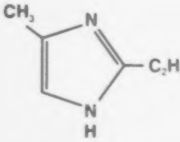
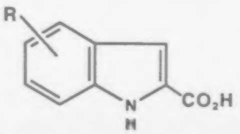


5-Amino-4,6-Dichloropyrimidine

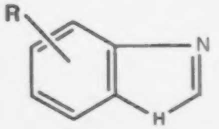
Pyridine N-Oxide



2-Ethyl-4-Methyl-Imidazole



Indole-2-Carboxylic Acids



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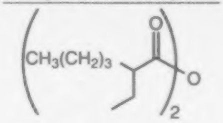
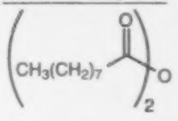
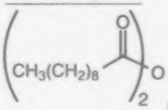


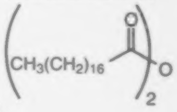
Nonanoic Anhydride



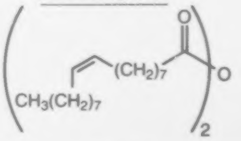
Lauric Anhydride



Stearic Anhydride



Oleic Anhydride



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Kaneka Corp. of Osaka and New York City has entered production of enantiomeric chemicals with a broad effort in biological methods. Industry observers rank Kaneka about neck-and-neck with the Andeno division of DSM Fine Chemicals in magnitude of chiral intermediates production. The company has a 1 million-kg-per-year amino acid plant in Singapore, that produces, among other compounds, D-phenylglycine and D-p-hydroxyphenylglycine as side chains for β-lactam antibiotics.

And another biological strength of Kaneka is immobilization of plant and animal tissue cells in polyvinyl formal resin. Drug company customers supply their cell lines, and Kaneka uses immobilized cells to produce bioproducts.

But the firm's plant in Takasago, Japan, also includes a full battery of equipment for synthetic chemistry. Marketing and development manager

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Conferences and expos introduce chiral drugs

Two series of annual symposia and expositions have become established in both the U.S. and Europe to present the latest offerings in enantioselective compounds, auxiliaries, technology, and services to customers. One of these, Chiral Europe '94, met this week in Nice, France. Meanwhile, Chiral USA '95 will be held in Boston, May 15–16, 1995.

Chiral matters often also form parts of conferences and exhibitions on fine chemicals, generally. For example, Chemical Specialities USA '94 will meet in Chicago, Oct. 18–20. One paper will address enantiomeric phase-transfer catalysts, and many exhibitors will feature enantioselective technology. ChemSpec Europe '95 will be held in Essen, Germany, June 20–22, 1995.

And for anyone especially interested in custom production of enantiomeric chemicals, the 10th Annual Informex Trade Show & Technical Symposium will be held in Nashville, Feb. 20–22, 1995.

Both Chiral USA and Chiral Europe symposia are organized by Spring Innovations, Stockport, England. Chiral USA '95 will feature 20 papers, delivered over two days by consultants and industrial and academic chemists, and an exhibit. Anyone in North America interested in Chiral USA '95 should contact Brandon Associates, P.O. Box 1244, Merrimack, N.H. 03054; phone (603) 424-2035. Those interested in Chiral Europe '95 should contact Spring Innovations, 216 Moss Lane, Bramhall, Stockport SK7 1BD, England. Phone number from the U.S. is 011-44 (61) 440-0082; fax 440-9127.

Chemical Specialities USA '94, also organized by Spring Innovations, will feature a symposium of 17 papers over two days and an exposition with more than 100 exhibitors. Brandon Associates is also the North American contact for this event.

Informex is sponsored by the Synthetic Organic Chemical Manufacturers Association (SOCMA) and focuses on custom chemical production. Many exhibitors feature enantioselective technology. Next year's meeting features a technical session, whose program is not yet fixed, and a two-day exposition. For information, contact SOCMA, 1330 Connecticut Ave., N.W., Washington, D.C. 20036; phone (202) 659-0060.

Joseph M. Marasco points with particular pride to the capability to run Birch reductions (dissolving sodium in liquid ammonia) at –100 °C. For this, the Takasago plant uses a Freon circulating to the reactor from a refrigerator compressor. As Marasco puts it, "We're not just 'the D-amino acid company.' " The firm does not bother with resolution of racemates, preferring instead to do asymmetric syntheses and enantioselective biotransformations.

Degussa has long used such a combined chemistry-biotransformation approach to make amino acids at its Rexim subsidiary in Courbevoie, France. Chemist Matthias Kottenhahn of the company's research center in Hanau, Germany, described the Degussa-Rexim approach to both D- and L-amino acids at ChemSpec Europe '94 in Manchester, England.

Such natural, protein-related L-amino acids as L-methionine are used in large volumes as animal feed additives.

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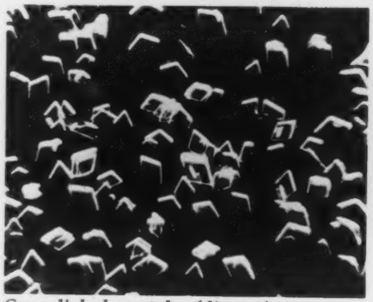
Altus Biologics photos

Cross-linked crystals of the protease thermolysin catalyze peptide syntheses.



Cross-linked crystals of lipase from Candida rugosa *enable resolutions of and syntheses for a broad range of chiral acids, alcohols, and esters.*

Nonnatural D-amino acids find applications in peptide drugs where their uncommon configuration makes them hard to hydrolyze. For example, D-alanine goes into the Pfizer artificial sweetener alitame.

The Degussa-Rexim process begins chemically with a classical Strecker conversion of aldehydes to racemic hydantoins with hydrogen cyanide, ammonia, and carbon dioxide. For L-methionine, the aldehyde is β-methylthiopropionaldehyde, and for D-alanine, it is acetaldehyde. The methionine hydantoin is hydrolyzed and acetylated to racemic *N*-acetylmethionine.

In a switch to biotransformation, an aminoacylase hydrolyzes only the L-acetylmethionine and leaves the D-isomer. That D-isomer is then racemized and the racemate sent back through the aminoacylase step.

In the route to D-alanine, the appro-

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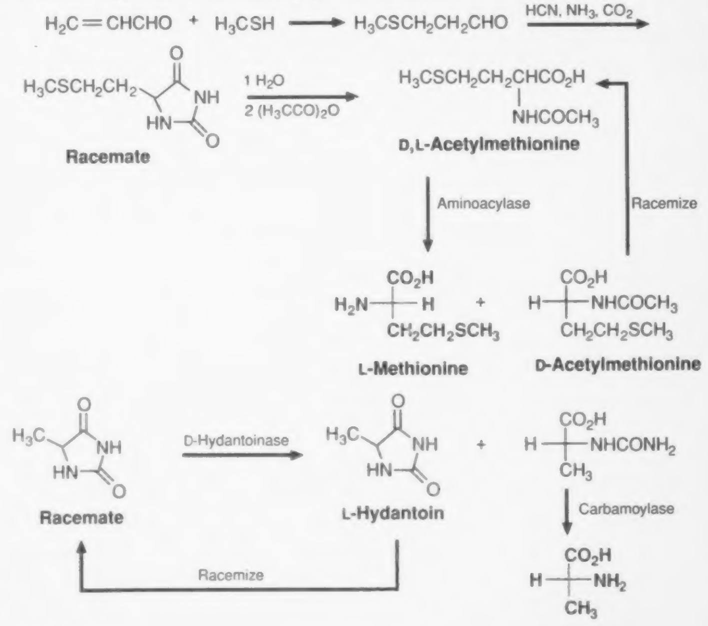
priate chemically produced racemic hydantoin is acted on by a D-hydantoinase, which hydrolyzes only that isomer, and then a carbamoylase, which frees up the D-alanine. Kottenhahn says that Degussa uses a biomass that has both D-hydantoinase and carbamoylase activity. The L-hydantoin is racemized and sent back through the bioresolution step.

At a large firm like Degussa, which can count on markets for large volumes of amino acids, it is possible to invest significant amounts of money to develop and perfect enzymes and processes. The picture is different for a smaller company like Celgene Corp. of Warren, N.J. Celgene must respond quickly to drug company orders for enantiomeric intermediates. Yet the probability is high that the particular drug will fizzle owing to sudden discovery of unacceptable side effects. Then Celgene could be stuck for all of the development costs to that point.

George W. Matcham, Celgene vice president and general manager for chiral products, explains that the company has responded by developing a very few key enzymes to high degrees of versatility. The result is that when a

Chemistry, biotechnology join in amino acid production


H2C=CHCHO + H3CSH → H3CSCH2CH2CHO
HCN, NH3, CO2
H3CSCH2CH2
NH
HN
Racemate
1 H2O
2 (H3CCO)2O
H3CSCH2CH2CHCO2H
NHCOCH3
D,L-Acetylmethionine
Aminoacylase
Racemize
CO2H
H2N
H
CH2CH2SCH3
L-Methionine
NHCOCH3
D-Acetylmethionine
H3C
Racemate
D-Hydantoinase
L-Hydantoin
NHCONH2
CH3
Carbamoylase
NH2
D-Alanine
Racemize

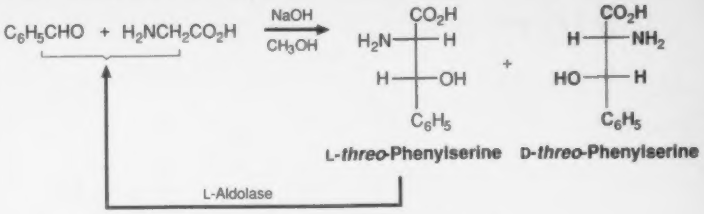
Source: Degussa

drug firm customer comes with an order for a highly specific single-isomer intermediate, Celgene will already have the enzyme needed to make it.

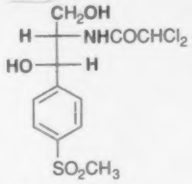
The company has concentrated on aminotransferases, aldolases, and a trio of nitrile-hydrolyzing enzymes. Aminotransferases catalyze reductive transfer of amino groups from amines to carbonyl compounds. An example is reaction of racemic α-phenylethylamine with propionaldehyde catalyzed by an (*S*)-aminotransferase to produce acetophenone and *n*-propylamine, leaving (*R*)-α-phenylethylamine unaffected as the desired product.

The original aminotransferases come from species of Bacillus and Pseudomonas bacteria, Matcham explains. Celgene inserts multiple copies of the genes for the enzymes into *Escherichia coli*, which are forced to overexpress them. This results in biomass containing large amounts of aminotransferase protein. The company also mutates genes by amino acid substitution or stress to improve their acceptance of certain substrates. The upshot has been the ability to make single-isomer amine intermediates at a cost of less than $1.00 per kg for the amino transfer step.

Chemistry and biotransformation make amino acids . . .



. . . which can be useful for drug production



Thiamphenicol

Source: Celgene

In one project that Celgene has permission to discuss, the company responded to an order for 2.9 kg of (*R*)-4-amino-1-(3-pyridyl)pentane from Hoffmann-La Roche of Nutley, N.J., which Roche wanted for use in making an experimental blood platelet activating

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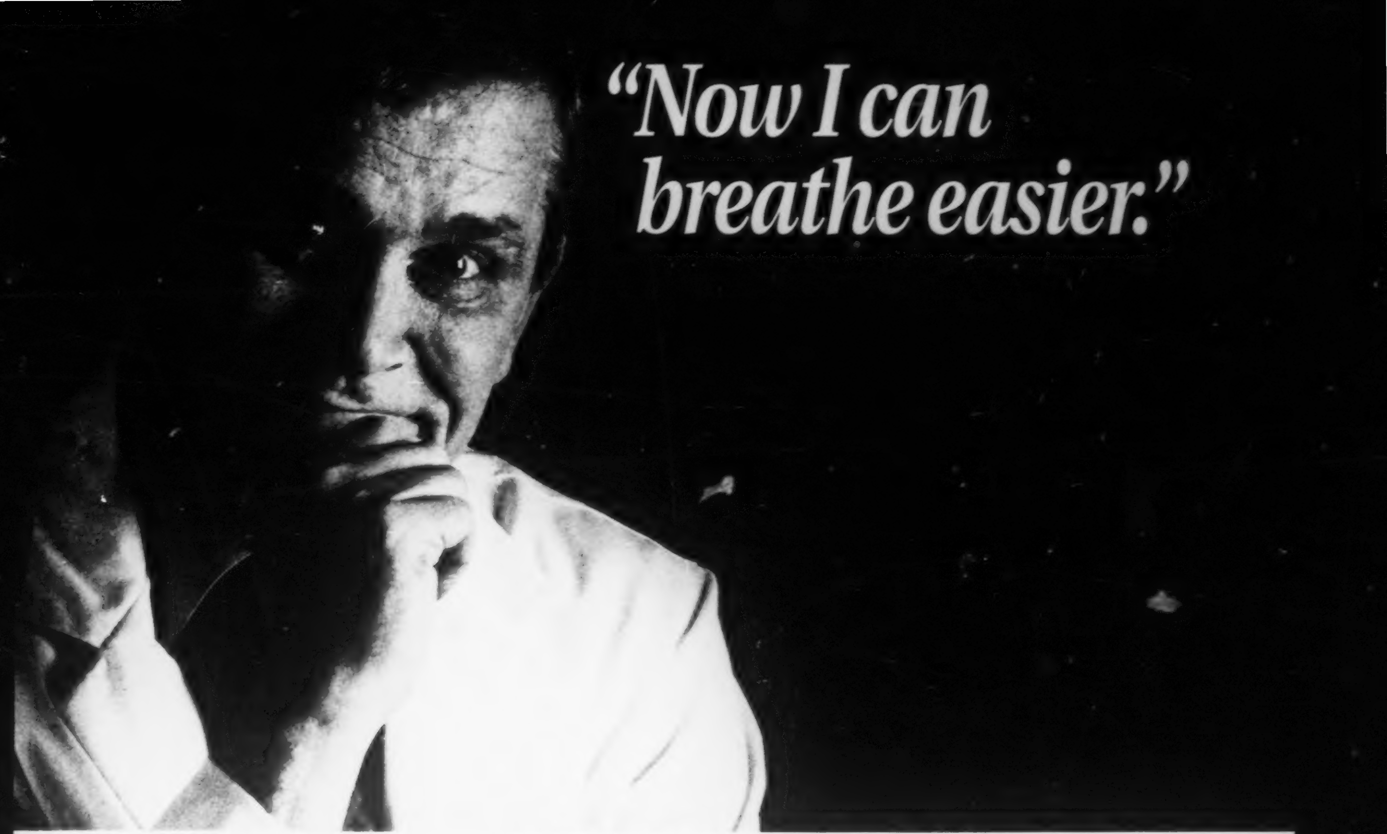
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CIRCLE 73 ON READER SERVICE CARD

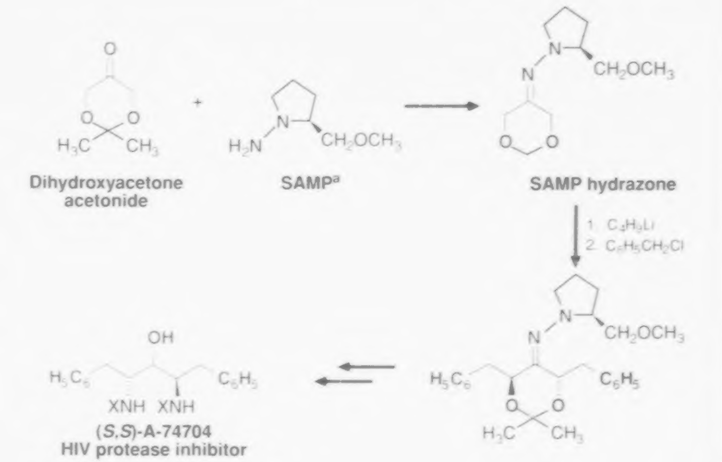
factor as a cardiovascular drug. Roche supplied the racemic amine. An off-the-shelf enzyme at Celgene converted the (S)-amine to a ketone, leaving the (*R*)-amine in more than 99% enantiomeric excess. Roche took back the ketone and subjected that to reductive amination (reaction with ammonia and hydrogen over Raney nickel catalyst) back to racemic amine.

An example of the use of aldolases is production of enantiomeric phenylserines. The D-*threo*-phenylserine isomer in particular is an intermediate in manufacture of such "phenicol" antibiotics as thiamphenicol. Just as Celgene can combine chemical conversions of ketones to racemic amines with enzymatic transaminations of racemic amines to enantiomeric amines and ketones, so the company can make racemic serine derivatives by chemical aldol condensations and degrade the unwanted isomer with an aldolase.

For phenylserines, Celgene condenses benzaldehyde with glycine. The condensation is reversible, and the threo-diastereoisomer drops out of solution preferentially. An L-aldolase degrades L-*threo*-phenylserine back to benzaldehyde and glycine, leaving the desired D-threo-enantiomer. Benzaldehyde and glycine can be recycled back to the racemic *threo*-phenylserine.

Though Celgene started out as an "enzyme company," the management has since realized that it needs synthetic chemical capacity as well. At the Warren site, Celgene has installed a

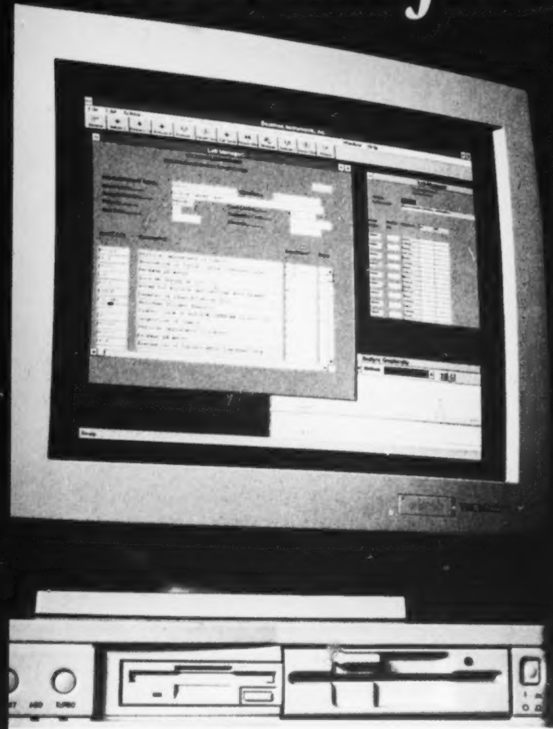
Method mobilizes aldehydes and ketones asymmetrically



XNH = benzyloxycarbonylvaline
HIV = human immunodeficiency virus

[a] SAMP = (*S*)-1-amino-2-methoxymethylpyrrolidine; the R isomer (RAMP) can be substituted.
Source: Rhine Westphalia Institute of Technology

Beckman just opened a window.



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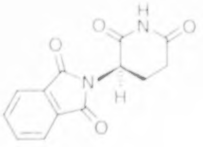
The recrudescence of thalidomide

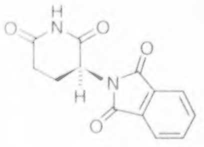
In discussions of chiral drugs, thalidomide is sometimes cited as a prime example of a drug that differs strikingly in the properties of its two enantiomers. It is alleged that only one enantiomer causes birth defects, whereas the other does not. Thalidomide was developed by Chemie Grünenthal of Aachen, Germany, in the mid-1950s as a sedative to prevent nausea during pregnancy.

In 1961, the compound was found to produce fetal limb abnormalities called phocomelia when taken in the first three months of pregnancy. Most countries promptly yanked thalidomide from the market. The U.S. narrowly averted approving it.

But in 1979, investigators at the University of Bonn, Germany, resolved thalidomide and reported that only the (*S*)-(–)-enantiomer is teratogenic in one strain of mice and Natal rats, and the (*R*)-(+)-form is not. To many people, the Bonn report has indicated that an innocuous enantiomer of thalidomide might yet be salvaged as a useful agent.



R



S

The matter involves more than just some effort to market one more sedative. Thalidomide has been found to inhibit replication of the AIDS virus, to clear oral canker sores in AIDS and other patients, and to ease erythema nodosum leprosum reactions (inflammatory skin flareups) in patients with leprosy, also called Hansen's disease. Indeed, doctors treating leprosy patients in the U.S. can get thalidomide from the National Hansen's Disease Center in Carville, La.

Also in the U.S., Celgene Corp. of Warren, N.J., has begun Phase II testing (clinical tests in a few hundred ill persons) of its Synovir brand of racemic thalidomide to treat weight loss in AIDS patients. Such weight loss seems related to abnormally high levels of the immune system messenger substance tumor necrosis factor-alpha (TNF-α) in AIDS. The clinical tests may provide results to indicate that thalidomide can reduce high levels of TNF-α.

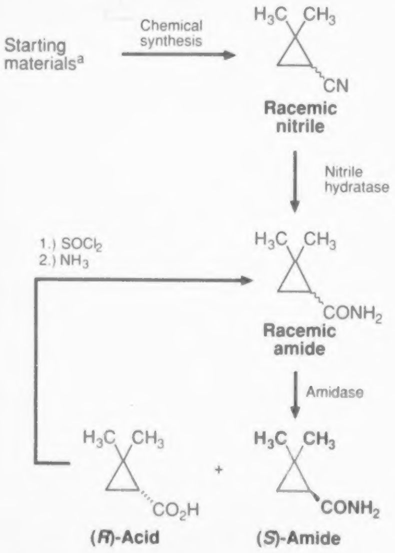
But as to differences between enantiomers, studies as early as 1967 at St. Mary's Hospital Medical School in London showed that both enantiomers of thalidomide are teratogenic in rabbits. And investigators at the University of Münster, Germany, found in 1984 that each enantiomer racemizes at physiological pH in test tubes or after injection into rabbits. These findings suggest that both enantiomers of thalidomide may be teratogenic in humans and that, in any case, either enantiomer of thalidomide would racemize once in the human body.

700-gal glass-lined reactor to handle swaps back and forth between chemistry and biotransformations. And the firm is looking to buy a large production plant.

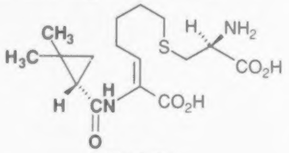
One company that has been wedded to classical resolution chemistry is Zeeland Chemicals, Zeeland, Mich., a part of Cambrex Corp. Zeeland uses enantiomers of mandelic acid to resolve racemic amines by fractional crystallization of diastereoisomeric salts. And it uses enantiomers of α-phenylethylamine to resolve carboxylic acids. Indeed, business development manager James K. Datson says the company's newest products are single isomers of α-*p*-methoxyphenylethylamine and *N*-benzyl-α-phenylethylamine as resolving agents and drug intermediates.

But Datson adds that Zeeland is moving into enzymatic methods of resolution. Nothing has yet been decided, but Zeeland's managers realize that the company needs to add biotransformations to its capabilities.

Synthesis and biotransformation combine to make intermediate . . .



. . . that is useful to produce an antibiotic potentiator



Cilastatin

a Several routes are known. **Source:** Lonza

Netherlands-based DSM Andeno is deepening its already broad involvement in biotransformations. DSM Andeno is the fine chemicals division of DSM Fine Chemicals. Andeno founded Chemferm, a joint-venture company, with Royal Gist-Brocades of the Netherlands at the beginning of 1994. Gist-Brocades is a major producer of penicillins, baker's yeast, and detergent enzymes. Chemferm is headquartered in the Netherlands and has a plant in Spain.

Chemferm will concentrate on production and marketing of bulk semisynthetic cephalosporin antibiotics. It is possible that Chemferm will be able to use aqueous enzymes to couple such side chains as D-phenylglycine onto the fundamental 7-aminocephalosporanic acid nucleus without needing to use the acid chloride in methylene chloride solvent. And in a further advance, Chemferm may discover an enzymatic process to use even cheaper racemic phenylglycine and couple only the D-enantiomer to the antibiotic.

A new direction in enzyme technology is the cross-linked enzyme crystals of Altus Biologics, Cambridge, Mass. Altus is a subsidiary of Vertex Pharmaceutics, a startup drug company also located in Cambridge.

Research director Alexey Margolin says Altus has added a cross-linked crystalline lipase from the yeast *Candida rugosa* to its peptidase product thermolysin. The lipase catalyzes a broad range of esterifications as well as hydrolyses. The thermolysin stitches peptides together and also breaks them down.

Altus first crystallizes the enzymes, then treats the crystals with glutaraldehyde. Bifunctional glutaraldehyde cross-links enzyme peptide chains by Schiff base reaction with pendant amino groups of lysine residues. Because the crystals are of single enzymes, Altus products avoid contamination with other enzymes that can occur in crude enzyme preparations. And cross-linked crystals function in such unusual solvents as 90% aqueous ethanol, 50% aqueous methanol, and pure ethyl acetate or dimethylformamide, as well as at temperatures as high as 55 °C.

Margolin gives selective hydrolysis of racemic methyl ester of ibuprofen to (*S*)-(+)-ibuprofen in 95% enantiomeric excess as an example of cross-linked lipase capability. And the protease can be used to assemble the three L-amino acids of the artificial sweetener aspartame.

The chirotechnology industry in the second half of the 1990s will see a growing number of participants and a growing number of capabilities. Early in the development of the industry, companies such as Bend Research of Bend, Ore.; Celgene, Chiroscience, Genzyme Corp. of Cambridge, Mass.; Peboc of Gwynedd, Wales; and Sepracor emerged as small firms operating in particular technology niches.

But as the chirotechnology industry has evolved, these companies have come to realize that their drug industry customers want products, not licenses to use proprietary technologies. As a result, these companies have begun to acquire commercial-scale production plants.

Other trends are apparent, as well. Companies that specialize in biotransformations are adding enantioselective synthetic organic chemistry to their portfolios. Large and small firms whose roots were in synthetic chemistry are developing or acquiring biological methods. DSM Andeno, for example, has sought a joint venture with enzyme specialist Gist Brocades. Lonza has bought a fermentation plant in the Czech Republic.

Companies that do not buy plants, develop new technologies, or enter joint ventures can expand their capabilities by means of informal alliances with one another. Examples are the cases of Chiral Technologies with UOP and Sepracor with Separex Chimie Fine.

The combination of these trends suggest that, in coming years, the chirotechnology industry is likely to evolve toward a few dozen uniformly capable companies that differ little from one another except in size. □

Five multiple firings detailed in report

The latest report on multiple terminations by the Subcommittee on Professional Standards & Ethics of the Council Committee on Economic & Professional Affairs (CEPA) gives details of five such terminations that occurred between August 1992 and June 1993. These terminations involved 95 job losses by chemical professionals.

The report, the 38th in a series dating back to 1974, indicates that an additional three multiple terminations have been verified and 16 as yet unverified reports are currently under investigation.

A multiple termination, as defined by CEPA, is a situation in which the employment of three or more chemical professionals is terminated by a single employer within a six-month period for reasons other than continuing evidence of previously documented inadequate performance, completion of a contract, or cause.

The reports have always been concerned only with job losses that are clearly involuntary. They do not provide a mechanism for investigating the "voluntary" separations and early retirement programs that have pervaded the chemical and related industries in recent times. Thus, the reports may not accurately reflect the employment picture for some chemical professionals.

According to the report, the committee's goal is "to provide an unbiased view of these terminations by gathering data from both the employer and the terminees . . . and to accurately and fairly describe contemporary industry practices to both chemists and their employers, so that expectations are grounded in recent experience, not myth or rumor."

But there have been numerous problems gathering information from terminees and from employers. In the current report, no employers agreed to provide details about their staff reductions. According to the report, "Typically, a company declines to participate, stating that they do not discuss personnel actions with those outside the company." For these and other reasons, these reports are slated to be discontinued after the next one is approved. CEPA will, however, continue to monitor and publish employment information via other sources.

The five multiple terminations detailed in the latest report were at A. D. Little, Cambridge, Mass.; Dow Chemical, Midland, Mich.; Koch Protective Treatment, Dayton, Ohio; Miles Inc., Tarrytown, N.Y.; and UOP, Tarrytown, N.Y. The largest was at Dow with 30 confirmed involuntary separations; the smallest was at UOP with four.

The three verified multiple terminations for which CEPA investigations are not yet complete were at DuPont, Twin City Testing, and Rohm and Haas.

As usual, the latest report compares the performance of employers with standards spelled out in ACS's Professional Employment Guidelines (PEG). These standards are concerned with advance notice, severance pay, assistance in finding new employment, length of employee service, and employee protection after termination.

Overall compliance with the PEG standards has remained fairly constant over the years. For the first 19 reports, through mid-1984, compliance was 42%; since then, it has been 44%. For this report, it was 42%.

The most discouraging news comes in the drop in compliance in meeting employee service standards. PEG standards call for no terminations of employees who have 10 years or more of service.

ACS Professional Employment Guidelines

- Advance notice. **Minimum of four weeks.**
- Severance pay. **Minimum is two weeks per year of service. Additional notice may be given, by mutual agreement, in lieu of severance pay.**
- Assistance. **Efforts should be made to place terminee in another position within the organization, or terminee should be given assistance to find employment elsewhere.**
- Employee service. **Those with minimum of 10 years' service should not be terminated except for continued evidence of previously documented inadequate performance or cause.**
- Employee protection plans. **Should be extended for a minimum of one month, plus two weeks for each year of employee service, following termination, at same rate of contribution as before. Employee would have additional 31-day grace period.**

Employer compliance with ACS employment guidelines

These data were received from employees	Approximate number of employees separated	Advance notice	Severance pay	Assistance	Employee service	Protection plans
A. D. Little (Cambridge, Mass.)	11	▨	▨	☐	▨	▨
Dow Chemical (Midland, Mich.)	30	▨	☐	☐	■	▨
Koch PTI (Dayton, Ohio)	6	■	☐	■	■	☐
Miles Inc. (Tarrytown, N.Y.)	9	▨	☐	☐	■	▨
UOP (Tarrytown, N.Y.)	4	☐	▨	☐	■	☐

☐ Employer met or exceeded guideline standard.

▨ Two or more individuals below guideline standard, but average experience better than "substantially below" criterion.

■ Employer was substantially below guideline standard, which is defined as follows:

- Advance notice—less than four weeks.
- Severance pay—less than two weeks per year of service.
- Assistance—no assistance rendered.
- Employee service—more than 30% of terminees had 10 or more years of service.
- Protection plans—no continuation of protection plans.

For the first 19 reports, compliance was 26%; since then, it has dropped to 14%. None of the employers in the current report complied with standards in this category. About 48% of all terminees in the current report appear to have had more than 10 years of service; among these, the average length of service was approximately 19 years.

Also slipping was compliance with PEG standards that call for four weeks' advance notice of termination. In the latest report, four of five employers—A. D. Little, Dow Chemical, Koch, and Miles—failed to meet this standard. UOP exceeded this guideline standard; all terminees reported between nine and 10 weeks' notice. Koch fell substantially below guidelines. Throughout the years, compliance with this standard has remained steady at about 40%.

The bad news may have been partially offset by some evidence of improvement in meeting the severance pay standard of two weeks' pay for each year of service. For the first 19 reports, only 16% of employers complied. For the second 19, compliance was 49%. This report indicated 60% compliance.

Compliance with the employee assistance standard has improved throughout the years, coming in at 80% for this report. The first 19 reports indicated 65% compliance; since then, compliance has risen to 85%. In the current report, only Koch failed to offer terminees résumé preparation and other services.

The PEG standard on protection plans calls for continuation of health insurance at employer expense for at least one month beyond separation. Compliance, 48% for the past 20 years, has declined during the past 10 years to 34%. The figure for the current report is 40%. Under the Consolidated Omnibus Budget Reconciliation Act of 1985, however, a terminee is entitled to continuation of benefits for up to 18 months. Inconsistent reporting of employers' actions—because of the widely different terms—may be the primary reason that employers appear to be falling short on meeting this PEG guideline.

Chemical professionals who have been fired or have taken early retirement are requested to contact the American Chemical Society, Office of Professional Services, 1155—16th St., N.W., Washington, D.C. 20036. Copies of all related C&EN stories are available, on request, from the same office.

Linda Ross

Undergraduate program popular at ACS meeting

The ACS national meeting in Washington, D.C., featured the first comprehensive program for undergraduates at a fall meeting. Activities designed specifically for undergraduate chemistry students drew nearly 400 participants.

Programming was designed to help students plan for the future by giving them the opportunity to learn about graduate schools, offering employment assistance and career information, and providing opportunities for networking with faculty and students from other schools.

Over the past several years, the Society Committee on Education (SOCED)—through its task force on undergraduate programming and the student affiliates program office—has been working to increase undergraduate participation in national meetings. Recognition of the importance of students to the future of the society and of the profession is prompting various ACS operating groups to jump on the undergraduate bandwagon.

In Washington, activities were sponsored by SOCED; Corporation Associates; the Younger Chemists Committee; the divisions of Chemical Education and of Small Chemical Businesses, the ACS staff offices of Local Section Activities, Public Outreach, and Career Services; and the National Chemistry Week Task Force, among others.

One of the most popular events on the program was a graduate school fair and reception. The event featured displays from 60 graduate departments and drew many interested students. Terri Nally, manager of the ACS Office of College Chemistry, reports that many graduate school representatives were delighted at the turnout—particularly at the proportionately large number of minority students at the fair. "If even a fraction of the students that we've seen talking to graduate school faculty end up applying to those programs, the effect on admissions of minority students to graduate chemistry programs at many schools could be profound," Nally says.

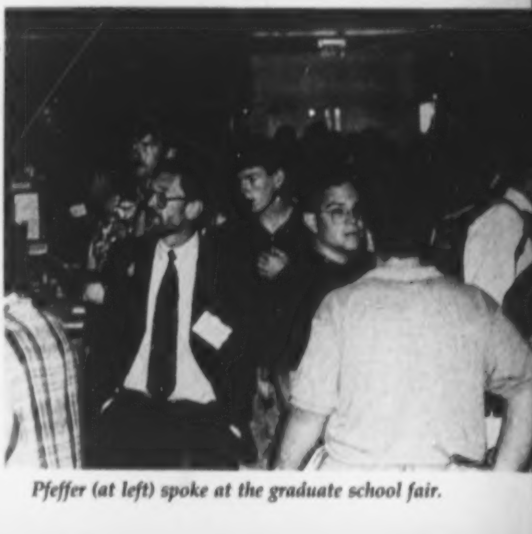
In addition to representatives from graduate programs and potential students getting to know each other, tips on the ins and outs of graduate school admissions were given by George Pfeffer, associate professor of chemistry at the University of Nebraska, Omaha. "Any chemistry faculty member has gone through the graduate school application process themselves," says Pfeffer, "so there is a lot of anecdotal information out there in addition to a lot of reference information—much of it produced by ACS." He reports that students were quite pleased to have so much of the information available in one place.

Slayton A. Evans Jr., professor at the department of chemistry at the University of North Carolina, Chapel Hill, helped students prepare for the not-so-distant future of next semester. He presented the meeting's Eminent Scientist Lecture using an interactive style to help students understand some aspects of stereochemistry.

Evans was encouraged by the interaction among students and faculty at the meeting. Our "clear objective [as teachers] should be to ensure that all students learn something new, either directly from the instructor's presentation or by listening to the dialogue between instructor and other students."

He believes that "encouraging and challenging students to share ideas and express their understanding of concepts through in-class dialogue promotes the learning process in a more profound way than simply by lecturing or presenting information." Before and after the lecture, he spent an hour or so talking with stu-

C&EN staff photos



Pfeffer (at left) spoke at the graduate school fair.

CHEMICAL & ENGINEERING NEWS

C&EN

SEPTEMBER 26, 1994

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Debate focuses on free market versus government mandate
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CHEMICAL & ENGINEERING NEWS
C&EN
SEPTEMBER 26, 1994

NEWS OF THE WEEK

- The U.S. has dramatically improved its competitive position in critical technologies—including materials and associated processing—during the past five years, says a new study. **Page 4**
- Critical Technologies Institute gets new, expanded role under the Clinton Administration. **Page 5**
- The International Union of Pure & Applied Chemistry apparently has acted on the controversy over the naming of transtermium elements 104 through 109. **Page 5**
- Plans announced by Shell Chemical and Huntsman Corp. could increase U.S. annual ethylene capacity by 1 billion lb by late 1996. **Page 5**
- The Environmental Protection Agency adopts a five-year strategic plan based on seven principles and designed to shape the agency's agenda into the 21st century. **Page 6**
- Carbon dioxide emissions must be drastically cut to stabilize atmospheric concentrations at current levels, according to a report by the Intergovernmental Panel on Climate Change. **Page 7**

COVER: Arco Chemical's methyl *tert*-butyl ether (MTBE) plant in Channelview, Tex.

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BUSINESS

Chemical sales and production in Germany are up as a result of restructuring in the industry, says Gert Becker, president of Germany's chemical industry association. **Page 17**

GOVERNMENT

EPA is revising guidelines for carcinogenic risk assessment to incorporate the latest thinking in cancer research. **Page 21**

One year after the project to reinvent government was initiated, federal agencies report successes in cutting red tape. **Page 23**

SCIENCE/TECHNOLOGY

Syntheses of porphyrins fused to extended aromatic systems will facilitate analysis of organic-rich sediments and help establish the origin of petroleum spills. **Page 25**

The high-resolution x-ray crystal structure of farnesyl diphosphate synthase—a key enzyme in the biosynthetic pathway to cholesterol and other steroids—has been determined. **Page 27**

BOOKS

Carl Djerassi's second "science-in-fiction" novel, "The Bourbaki Gambit," deals with the issue of ageism and conveys to the reader other important aspects of the culture of scientists. **Page 29**

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Candidates for 1995 president-elect, for Region I director, for Region V director, and for directors-at-large present their statements to members. **Page 31**

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The 33rd Eastern Analytical Symposium in Somerset, N.J., Nov. 13–18, will feature 63 oral and poster sessions, an exposition, 22 workshops, 17 short courses, and six award symposia. **Page 46**

NEWS FOCUS

A recent court decision adds further to the debate on whether the government should mandate use of ethanol as a gasoline oxygenate or whether market forces should be allowed to determine the most cost-effective oxygenate to meet Clean Air Act goals. Page 8

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LETTERS

Regulation strangling business

Albert S. Matlack (C&EN, Aug. 29, page 2) goes to great length to defend the regulatory environment that is strangling U.S. business. He castigates the Business Roundtable for calling the current system costly and inefficient, yet offers no evidence that it is not. He says that "regulation at the federal level has the advantage of providing a level playing field," yet doesn't mention that the level is now so high that anyone without a helicopter can't play the game.

Matlack touts the many jobs and businesses created by the cleanup and one sentence later states, "The main loss in innovation has been the curtailment of exploratory research as a result of corporate downsizing." It apparently doesn't occur to him to question where those jobs were created and why downsizing occurred.

The Fortune 500 company that employs me has had no change in the size of its R&D staff for the last 14 years, but our employment of regulatory compliance staff has exploded. The U.S., with 5% of the world's population, has more lawyers than the rest of the world combined. If we could say the same for our scientists and engineers, we would not be struggling with our balance of trade and could easily focus on solving the problems rather than litigating them.

Robert M. Holdar
Irving, Tex.

U.S. jobs, immigration

I take issue with Kenneth Cohrs' letter (C&EN, Aug. 22, page 5) that strongly implies that there is a direct link between the increase in immigration of highly skilled scientists and engineers and the unemployment rate of U.S. chemists.

Science and technology are highly competitive fields of endeavor that recognize no borders or national or ethnic origins of their practitioners. Highly trained foreign chemists who join our scientific pool tend to stimulate and expand scientific activities. There are countless immigrant chemists, who in the past have made, and many who still are making, significant contributions to U.S. science and technology.

I want to mention just a few contemporary, distinguished immigrant chemists who have been honored by ACS: Sir Derek Barton (Nobel Laureate), Carl Djerassi, Gilbert Stork, Bernhard Witkop, and Alfred Bader (former chairman and founder of Aldrich Chemical Co., known to all organic chemists).

Anyone who reads research articles in scientific journals will notice the numerous exotic, foreign names that represent foreign coworkers and postdocs who are the hands-on workers of so much of this country's academic research. My own experience has been that few U.S. graduates apply for these positions because of poor pay, long hours, and little prospects for advancement. I believe the level of unemployment of chemists in the U.S. during the past couple of years has more to do with the recession, downsizing of defense industries, and insecurity in the pharmaceutical industry than with immigration.

Josef E. H[illegible]z
Houston

Federal technology transfer

National laboratories have been under the gun for many years to justify their continued expenditure of huge sums of tax dollars. Most often, "technology transfer" is mentioned as a yardstick of value, but as Wil Lepkowski points out in his recent article, "Federal Labs Examine Strategies for Meeting Technology Transfer Goals" (C&EN, Sept. 5, page 17), "a policy that optimally translates results of publicly funded R&D into competitive industrial products has eluded everyone." One can raise the question of whether there is much technology to transfer.

Department of Energy laboratories in particular have produced only one well-known R&D result: nuclear devices. Although some of this technology was transferred to the private sector (for example, reactors), much was not. Little else in the way of industrial products or new technology has sprung from the vast sums that have been consumed by DOE laboratories over the many years since the Manhattan Project days. The question of how much useful technology is being produced should be examined.

In some cases where there is evident technology to transfer, the DOE bureaucracy has prohibited the realization. An example was the failure of a potentially large-scale transfer of gas centrifuge enrichment technology that was left on the shelf after abandonment by DOE in 1985. Taxpayers spent billions on this already developed enrichment technology that was sought by a private-sector firm to be

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Court Ruling Spurs Continued Debate Over Gasoline Oxygenates

Key point is whether government or market forces should determine use of a particular oxygenate to meet 1990 Clean Air Act standards

George Peaff, C&EN Northeast News Bureau

The debate over gasoline additives has been in progress since the phaseout of lead antiknock additives began in the early 1970s. Mandated by Environmental Protection Agency (EPA) rules promulgated in 1989, octane enhancers that were used to replace lead alkyls began to be used as gasoline oxygenates. And the debate, until now, has largely focused on their health effects, their effects on automobiles, and whether they are as good for the environment as their proponents claim. However, the debate has now shifted to another arena. Put frankly, it is whether the government can mandate a particular oxygenate, in this case ethanol, or whether market forces should determine the most cost-effective oxygenate to obtain the required clean air results.

The U.S. Court of Appeals for the District of Columbia Circuit earlier this month granted a stay on EPA's ethanol mandate. That decision will give full hearing to the debate over the economic, regulatory, and political issues surrounding the reformulated gasoline regulations that are part of the 1990 Clean Air Act.

EPA's decision to mandate by 1996 the use of ethanol and other oxygenates from renewable sources in 30% of reformulated gasoline marketed in the U.S. has resulted in a firestorm. It pits free-market forces and the petroleum industry against government mandates and the ethanol industry, which includes corn farmers who supply the key raw material for making ethanol.

"We are suing EPA because its ethanol mandate is neither legal nor rationally defensible," says Charles J. DiBona, president of the American Petroleum Institute (API).

EPA Administrator Carol M. Browner protests this characterization. "EPA's fuels program reflects the Clinton Administration's commitment toward cleaning the air and reducing summer smog."

The pending case and remonstrance from various sources against EPA's mandate focus on the tax, environmental, and health issues surrounding ethanol and two other oxygenate contenders. One is ethyl *tert*-butyl ether (ETBE), derived from ethanol and isobutylene, and the other is methyl *tert*-butyl ether (MTBE), mainly derived from methane and isobutylene.

The first phase of EPA's ethanol mandate, requiring 15% of reformulated gasoline to contain oxygenates from renewable resources, is scheduled to take effect Jan. 1, 1995, unless the court or Congress overturns EPA's ruling.

Most MTBE makers could readily switch their plants to make ETBE after some production modifications. However, the petroleum industry, represented by API and the National Petroleum Refiners Association (NPRA), have looked to set aside EPA's renewable oxygenate mandate. In July, they petitioned EPA to issue a stay on the ethanol mandate and concurrently filed suit in the court asking it to issue a stay or reverse the EPA rule. The American Methanol Institute (AMI), as representative for methanol producers, joined the suit in August.

In summary, the suit says EPA's original rule "precludes adoption of a [reformulated gasoline] rule without air quality benefits and does not permit a mandate for any particular oxygenate." The suit also says the statute has not considered properly the environmental, economic, energy, and health issues surrounding the ethanol mandate.

In addition, the suit claims that gasoline producers and distributors will suffer "irreparable injury" since they will not be able to recover the added expenses required to meet the mandate and that the five-month lead time to prepare for the mandate is impractical. It also cites that the petroleum industry already uses ethanol in gasoline as dictated by market factors, and that "the ethanol rule is nothing more than a windfall to ethanol producers . . . at the overall expense of gasoline consumers, producers, or both." Because of the 54-cent-per-gal ethanol tax subsidy, the suit claims "hundreds of millions of dollars" will be subtracted from the Highway Trust Fund.

But in late August, EPA denied the petition for a stay, and in its mid-September ruling, the Court of Appeals granted the stay, but did not issue a summary reversal as

Of oxygenates, ethanol offers most oxygen

	ETBE	MTBE	Ethanol	Summer RFG[a], southern grade
Octane rating	112	110	115	88
Blending RVP[b] (psi)	4	8	18	7.2 maximum
Oxygen content (weight %)	15.7	18.2	35	2.0 minimum
Oxygenate % by volume to achieve 2.0 weight % oxygen	12.8	11	5.7	

a RFG = reformulated gasoline. b RVP = Reid vapor pressure.
Sources: Arco Chemical, SRI International

asked for by API, NPRA, and AMI. Rather, the court decided to hear the case in early 1995, allowing all parties to present all sides of the case.

Opponents, namely gasoline refiners and distributors and MTBE and methanol producers, claim that market forces should be allowed to determine the most cost-effective product to be used to achieve the oxygenate standards required by the Clean Air Act of 1990. Predictably, these opponents of the mandate welcome the court's decision to hear the case and express confidence the court will decide against the mandate.

Supporters of the mandate point to ethanol as a renewable alternative to MTBE, reducing U.S. reliance on foreign-produced fossil fuels, increasing jobs for corn farmers and ethanol distillers, and cutting farmers' reliance on federal farm subsidies. Predictably, these supporters condemn the court's decision, with EPA saying the court will take the agency's side after reviewing the merits of the case.

Gasoline distribution terminals, such as this one operated by Shell Oil, could be required to blend ethanol with gasoline just before transporting it to gas stations.

Ethanol, as used in gasoline, is mainly fermented and distilled from corn grown by U.S. farmers. Its ether derivative, ETBE, is produced by combining ethanol with isobutylene. MTBE is produced by substituting ethanol with methanol, which is usually derived from natural gas. Although refiners purchase methanol from a number of producers or make it themselves, ethanol must be purchased by refiners and distributors, depending on what form of it is blended into gasoline: straight, as is now the case, or as part of ETBE. The catalysts used to produce MTBE and ETBE also differ, and an ETBE plant would require additional equipment.

The mandate decision emanated from the discussions and hearings held by EPA and the many interested parties involved, including automakers, environmental groups, and the agriculture, ethanol, and petroleum industries. Although the mandate has temporarily been rescinded until a final determination can be reached, EPA has indicated that the reformulated gasoline program will go into effect as scheduled.

But the rocky relationship between ethanol and ETBE and between methanol and MTBE goes back several years, as all four have had dual purposes at various times in various combinations to help achieve EPA's earlier dictate to replace lead-based gasoline additives—tetramethyllead (TML) and tetraethyllead (TEL)—used as octane enhancers in gasoline. Ethanol and methanol at one time were also under development for use as fuel alternatives to gasoline.

In 1973, EPA began the phaseout of lead octane enhancers, and gasoline was allowed to contain no more than 2 g per gal. The agency tightened the restriction in 1986 to 0.1 g of lead per gal, with all lead to be eliminated by 1996.

Before the phaseout of TML and TEL, about 20% by volume of gasoline was made up of aromatics, explains Arthur Zadrozny, manager of government outreach oxygenated fuels at Arco Chemical, a major supplier of both MTBE and ETBE. Aromatics levels reached close to 40% by volume in some grades of gasoline to replace the octane lost with the removal of lead additives, he says.

Beginning in 1989, in an attempt to lower emissions of ozone-producing volatile organic compounds (VOCs) from evaporating gasoline in the summer months, EPA established regulations to reduce the Reid vapor pressure (RVP). RVP is a measure of a liquid's volatility.

In Phase I of the program, RVP was reduced to between 9 and 10.5 psi from May 1 to Sept. 15, with the range determined by geographic area. Nationwide in 1989, RVP of gasoline averaged 11.5 psi.

To meet the RVP reduction program, gasoline producers reduced the amounts of butane blended into gasoline and added more oxygenates along with adjusting reformates and alkylates to make up for the loss of butane. MTBE became the most frequently used octane enhancer. Unleaded regular gasoline usually contains about 0.2% by volume of MTBE, but can range as high as 2.5% by volume, and ranges between 2 and 9% by volume in unleaded premium gasoline.

Phase II of the summer gasoline program was instituted in 1992, but became part of the Clean Air Act amendments. Under the amendments, automotive exhaust emissions of carbon monoxide, nitrogen oxides, VOCs, and toxics including benzene, butadiene, acetaldehyde, and formaldehyde were to be reduced. Again, adjustments to the blending of gasoline were made, mainly leading to the increased use of oxygenates such as ethanol, but primarily MTBE, to meet pollution reduction goals while maintaining octane requirements.

The RVP reduction program's second phase required an average RVP in gasoline of 9 psi in May in 24 southern states; 7.8 psi from June to September in the 24 southern states; and 8.2 psi from May to Sept. 15 in the 26 other states.

In November 1992, the oxygenated gasoline program went into effect requiring gasoline to contain 2.7% by weight of oxygen—equivalent to 15% by volume of MTBE—during the four winter months in the 39 metropolitan regions not meeting EPA's carbon monoxide reduction standards.

The reformulated gasoline program, to be instituted in January 1995, requires nine metropolitan areas with high

Mandate pits farmers against oil producers

Entities against ethanol mandate	Entities for ethanol mandate
American Methanol Institute	Environmental Protection Agency
American Petroleum Institute	Clinton Administration
Exxon	23 farm groups, including National Agricultural Chemicals Association and National Corn Growers Association
Mobil	Fuels for the Future
National Petroleum Refiners Association	
Shell	
Sierra Club	

ozone pollution levels—New York City, Philadelphia, Baltimore, Chicago, Milwaukee, Houston, Los Angeles, San Diego, and Hartford, Conn.—as well as portions of 14 states and Washington, D.C., to meet several standards. Other cities may opt into the program.

Gasoline must have an oxygen content of 2.0% by weight. Benzene content cannot exceed 1.0% by volume. Aromatic content cannot exceed 25% by volume unless benzene content is lower than 1.0% by volume. RVP levels must be 8.1 psi in the northern states and 7.2 psi in the southern states.

Although MTBE, ethanol, and ETBE serve both as octane enhancers and oxygenates, the three have chemical, performance, environmental, and economic advantages and disadvantages depending on what purpose their use takes on.

Ethanol has an octane rating of 115, versus 112 for ETBE and 110 for MTBE. To achieve a 2.0% by weight oxygen content per gallon of gasoline, 5.7% by volume of ethanol would be required versus 12.8% by volume for ETBE and 11% by volume for MTBE.

But use of ethanol raises RVP of gasoline. Ethanol's RVP is 18 psi, compared with 4 psi for ETBE and 8 psi for MTBE. To meet EPA requirements for VOCs, ethanol could not be used in most areas in summertime gasoline. The use of ethanol in gasoline also slightly raises nitrogen oxide emissions as compared with both ETBE and MTBE.

Gasoline containing MTBE has become recognizable—as its concentration in gasoline has risen—by its pungent odor, which has led to consumer complaints in several states. This has also led to further studies on whether MTBE presents a health risk to both its handlers and consumers. While MTBE has undergone several studies to determine its health risks, little study has been done on ethanol and ETBE.

In EPA's latest comprehensive health report concerning MTBE—issued in November 1993—the agency concludes: "There is unlikely to be a substantial risk of acute health symptoms among healthy members of the public receiving 'typical' environmental exposures under temperate conditions (meaning, not subarctic temperatures). This leaves the question open about more subtle health risks, especially among susceptible subpopulations. If acute symptoms are being caused by MTBE, they appear to be mild and transient."

EPA cites several studies (C&EN, Sept. 20, 1993, page 9) conducted on workers and drivers exposed to MTBE in gasoline and MTBE exposure tests in animals. The agency determined that "it does not appear that there is a significant risk for MTBE to cause chronic noncancer effects" by itself, but that when in a mixture with other components in gasoline, the potential noncancer health effects were not known. And EPA also reported, "At the present time and on a tentative basis, there is no reason to say there is a serious carcinogenicity public health hazard from the inhalation of MTBE, although some hazard is possible and necessarily should be further evaluated."

As presented at the American Chemical Society's national meeting in Washington, D.C., last month, a study conducted by the Institute of Arctic Biology at the University of Alaska, Fairbanks, concluded that the gasoline produced for Alaska's 1992 oxygenated fuels program differs from gasoline refined in the lower 48 states. The higher recognition of MTBE odor in Alaskan gasoline, as reported by residents of Fairbanks and other areas, arises because the gasoline originated from North Slope crude and was refined using a different process than gasoline refined in other states.

Using 21 Fairbanks resident volunteers, the study tested six fuels made either from Alaskan or other states' gasoline—both types with 15% by volume MTBE, both with isopropyl alcohol, and both without either MTBE or isopropyl alcohol. Temperatures ranged from –24 to +25 °F to duplicate winter conditions. Odor recognition was eight times that for the Fairbanks MTBE-containing gasoline than for MTBE-containing gasoline from other states. Odors from the two gasolines containing isopropyl alcohol were indistinguishable. The institute also determined that Alaskan gasoline contains "a higher proportion of aromatic compounds than lower 48 fuels" and other states' gasoline "emitted higher vapor concentrations of MTBE across temperatures."

Just as refiners were required to blend MTBE into gasoline to meet Alaska's oxygenated fuels requirement, gasoline refiners and distributors will be required to blend more ETBE or ethanol, respectively, into gasoline distributed to filling stations as a result of the ethanol mandate. Currently, MTBE is the primary oxygenate used because it is the least expensive and is in greater supply than both ethanol or ETBE.

Ethanol poses another problem to refiners, pipeline firms, and distributors. Gasoline using MTBE or ETBE can be blended into gasoline as it is being produced at the refinery and can be shipped via pipeline. Ethanol must be "splash blended" into gasoline just before being transported to a filling station to guard against its hydrophilic properties.

To meet the ethanol mandate, terminal operators would incur costs to transport ethanol to their facilities and they would also have to build additional storage capacity. Refin-

Ethanol ruling shifts oxygenate demand

Millions of gal	1993	2000	% change
Gasoline	113,181	113,779	0.5%
MTBE	3,235	10,854/7,604[a]	236/135
Ethanol	997	2,589[b]	160
ETBE	0	3,249[c]	na

a Represents demand without/with ethanol mandate. **b** Represents demand with ethanol mandate; without mandate, demand would not change over 1993. **c** Represents demand with ethanol mandate, including 1.59 billion gal of ethanol required to produce ETBE. **na** = not applicable. **Source:** Probe Economics

Goldberg: try to find joint areas of cooperation

eries would be required to do the same for ethanol intended for ETBE production.

And as explained by Chuck Shepherd, manager of business development and planning for oil products at Shell Oil, Houston, gasoline pipeline operators would face another complexity. "The gasoline blending stock that would be used to mix with ethanol to produce reformulated gasoline . . . would be slightly different than conventional gasoline," he says. Gasoline to be mixed with ethanol would have to be blended with a lower RVP.

Currently, gasoline pipeline operators potentially deal with 18 grades of gasoline. Taking into account the three octane levels available, three grades would be of conventional gasoline—which may contain MTBE as an octane enhancer—three grades would contain MTBE serving as the oxygenate, and three grades would have adjusted RVP for ethanol blending. These nine grades double to 18 in order to meet the two sets of RVP requirements for winter and summertime gasoline.

Since most of the ethanol producers are in the Midwest, use of ethanol in gasoline now is restricted to that region because it is cost effective versus piping MTBE-containing gasoline from outside the region. "A number of suppliers have used ethanol in the past as their oxygenate of choice in those markets where it is readily available," confirms Shell's Shepherd.

However, if the ethanol mandate is upheld, because of the ability to ship ETBE-containing gasoline via pipeline, that blend would be added to the 18 grades of gasoline existing, bringing the total to 24 grades of gasoline. "The efficiency of the pipeline operations is something that is of concern and is questionable right now," states Shepherd.

He cites petroleum industry estimates that moving ethanol and installing terminal facilities could add 2 to 4 cents per gal to the price of gasoline, depending on the region the ethanol is shipped to.

Only part of the outcry against ethanol stems from its usage difficulties. "There is something obscene about the argument that a substitute for gasoline that is already subsidized by the taxpayers at more than the total cost of an equivalent amount of gasoline must also have a mandate requiring its use," said API's DiBona in a statement made when API and NPRA filed suit against EPA's ethanol ruling in July.

"The clear winner from the mandate," DiBona said, "is Archer Daniels Midland (ADM). ADM controls two thirds of U.S. ethanol production, and ADM would receive more than half of the money generated by this decision."

ADM is the largest ethanol producer—for use in fuel—in the U.S., with its four plants having combined annual capacity of 700 million gal. Several smaller producers—including Pekin Energy, New Energy Co., South Point Ethanol, A. E. Staley, and Cargill—have a combined annual capacity of 600 million gal of ethanol.

The subsidy API's DiBona refers to actually comes in the form of two tax credits. Under Treasury Department rules, distributors of gasohol, a combination of 10% ethanol and 90% gasoline, can subtract 5.4 cents off their federal excise tax for every gallon of gasohol sold. A 100% ethanol fuel would result in a 54-cent-per-gal excise tax credit. The size of the tax credit drops proportionately to the percentage of ethanol used in gasoline. Various states also have tax credits for the use of ethanol in fuels.

Buyers of ETBE—refiners—could also take a tax credit against their income tax, based on the ethanol content of ETBE. But producers of ETBE cannot take a tax credit for buying ethanol because they are not blending it directly into gasoline.

As explained by Arco Chemical's Zadrozny, ETBE producers pay a premium for ethanol as compared with methanol, and then try to pass the extra cost to the buyer, who gets to take an income tax credit. "Right now, the ether producer must pay the going price for ethanol and then hope to recover this cost in the marketplace," he adds.

However, under the present tax rules, refiners may not be able to take the full tax benefit. "The income tax credit that [the refiners] could realize from using ETBE may be of no value to them because they don't have any tax liability left to credit it against," says Zadrozny. A gallon of ETBE contains 42% ethanol. Using a 10% blend of ETBE in gasoline would result in a potential income tax credit of 2.3 cents per gal of gasoline.

In mid-September, consensus estimates from various commodity chemical and petrochemical consultants placed the spot price for ethanol at $1.25 to $1.30 per gal, MTBE at 90 to 93 cents per gal, and methanol at $1.25 to $1.32 per gal. ETBE currently has no spot price, since its production and use are still in various trial stages.

Arco has taken an "alcohol neutral" position on oxygenated fuels, since it has the capability to produce both ethers. It has U.S. production capacity for MTBE of 800 million gal per year, largest of the 27 current producers. U.S.-based capacity for MTBE totals 3.12 billion gal.

As for ETBE, Arco's Corpus Christi, Tex., plant, leased from Coastal Refining, has a 185 million-gal annual capacity interchangeable for both ETBE and MTBE. Amoco Oil has a test facility for ETBE in place at its Yorktown, Va., site, and Chevron Chemical has a convertible 30 million-gal ETBE/MTBE facility in El Segundo, Calif.

Exxon, Mobil, and Shell, as producers of MTBE, have all come out against the ethanol mandate. "We believe the ethanol mandate violates the intention of the Clean Air Act to be fuel neutral," says Shell's Shepherd.

A spokesman for Mobil says the company is against government mandates and that the market will determine which oxygenate will be used to meet reformulated gasoline requirements. Mobil has used ethanol in the Phoenix and Minnesota markets, he adds.

And an Exxon spokeswoman says the company "strongly opposes" the mandate. "We believe it is beyond the scope of EPA's statutory authority and is an example of ill-advised government intrusion into the marketplace for the purpose of subsidizing and promoting one specific product over others having identical air quality effects." The spokeswoman adds that the company supports API's challenge in court.

The amount of gasoline to be affected by the mandate has often been distorted by the opposing camps. Backers of ethanol, including EPA, have said only a small portion of gasoline consumed will be made from renewable sources. "In the context of overall gasoline usage, this program will result in only 0.5% of the gasoline consumed annually in the U.S. being made from renewable sources," says EPA's Browner. She refers to the mandate as it is to begin in January 1995, requiring 15% of reformulated gasoline to contain oxygenates from renewable sources.

But the 0.5% is a misleading figure, several sources claim. Whereas 0.5% of the total volume of all gasoline produced in the U.S. would have to contain ethanol, a much greater portion of gasoline would be affected.

"That's a misuse of statistics," explains Zadrozny. "If you take the whole gasoline pool, about 35 to 40% of it is going to be reformulated gasoline." He bases his estimate on looking at the geographic regions where reformulated gasoline must be used and the petroleum industry's projected demand for gasoline in those areas.

A look at gasoline market figures back both Zadrozny and Browner. According to Fred Peterson of Millwood, N.Y.-based Probe Economics, U.S. demand for gasoline in 1993 was 310 million gal per day, or 113 billion gal per year. By 2000, demand is projected at only 312 million gal per day, or 114 billion gal per year, he says.

Looking at MTBE, ethanol, and ETBE as both octane enhancers and oxygenates, Peterson estimates that demand for MTBE in 1993 totaled 8.9 million gal per day, or 3.23 billion gal per year. By 2000, MTBE demand could reach 29.7 million gal per day, or 10.9 billion gal per year. As for ethanol, Peterson projects use in gasoline in 1993 at 2.7 million gal per day, or 997 million gal per year. But with the reformulated gasoline mandate, demand, including ethanol used in ETBE, could rise to 7.1 million gal per day, or 2.58 billion gal per year.

If, in 1995, gasoline demand totals 113 billion gal, under reformulated gasoline requirements 35%—or 39.5 billion gal—would be oxygenated using either MTBE or ethanol. Under the 15% mandate, 5.93 billion gal of gasoline would contain 336 million gal of ethanol to get 2.0% by weight of oxygen within the gasoline. But to get full tax credit for the ethanol used, 10% by volume would be blended, resulting in 593 million gal per year of ethanol used, or 0.5% of the total volume of gasoline, the volume referred to by Browner.

Zadrozny: some tax credits have no value

Kearney, Neb., corn farmer Gary Goldberg, also president of the 12,000-member American Corn Growers Association (ACGA), views the demand for oxygenates from a different perspective. He takes a stand for the greater use of ETBE, citing its lower RVP and ability to be shipped via pipeline. "Right now, [of all] the gasoline pumped in the U.S., only 1% of it is ethanol," he says.

Although admitting ACGA backs EPA's decision, Goldberg says ACGA is unlike some 22 other agricultural organizations, including the 260,000-member National Farmers Union and the 28,000-member National Corn Growers Association, because it is promoting cooperation between the petroleum interests and the ethanol interests. "No other farm organization in America, whether it be a general organization or a commodity group, is talking about ETBE except us. If you were to have the tax credit for ETBE, we believe that we would be able to meet the 15% mandate for 1995 and the 30% [for 1996]."

Goldberg emphasizes that the confrontation between the two sides accomplishes little. "We can fight. We can spend millions of dollars in legal challenges and full-page ads in the *Washington Post*, or we can sit down and say, 'What could we do to try to find joint areas of cooperation?' "

He contends that the long-term interests of the two groups "might not be that far apart. ADM, Staley, and all these ethanol companies do not own their own gas stations. Not one gallon of ethanol would be marketed [for gasoline] if it wasn't a petroleum marketer doing it."

The views of both the agricultural industry and the ethanol industry concerning the reformulated gasoline debate have been distributed by Fuels for the Future, a Washington, D.C.-based information clearinghouse supported by agricultural groups, renewable fuels producers and distributors, consumer organizations, and others. The clearinghouse collects and distributes news concerning clean fuels, clean air, and clean water.

In the months before and after EPA originally set the mandate, each side attacked the other through advertising in various print media and press releases distributed over the various wire services.

By number and content, the ethanol interests, mainly through Fuels for the Future, have been the aggressors in the debate, with the petroleum interests counterattacking. MTBE and its key ingredient methanol were portrayed as poisons and carcinogens if inhaled or drunk, as posing potential health risks, or as perpetuators of the U.S.'s dependence on foreign fossil fuel sources.

API and NPRA jointly, and/or AMI, countered that both methanol and MTBE are poisonous if ingested, may or may not be a cause of cancer, and may or may not cause other health risks. All three also noted, however, that ethanol, ETBE, and MTBE were approved by EPA as gasoline additives, even as their efficacies were being debated.

Pure ethanol, as used as a gasoline additive, is itself poisonous, as can be the ethanol—in diluted concentrations—in alcoholic beverages. And ethanol, as viewed by EPA, may or may not be a cause of cancer. Gasoline is also poisonous and may or may not be a carcinogen.

A marked illustration of how the two sides portray the issue occurred during the Senate debate of an amendment to prevent funds for implementing the EPA ethanol mandate. The amendment was to be part of the Veterans Administration, Housing & Urban Development, and Independent Agencies appropriations bill for fiscal 1995.

Introduced by Sen. J. Bennett Johnston (D.-La.), the amendment was also supported by Sen. Bill Bradley (D.-N.J.), an outspoken critic of the EPA mandate. It received endorsement from API, NPRA, and AMI.

In separate releases, Fuels for the Future listed 22 farm organizations and five environmental organizations aligned against the amendment. Although the farm organizations were against the amendment but for the mandate, the environmental organizations' opinion on ethanol as an oxygenate was not an issue in their siding against the amendment.

In a letter to various Senators, the environmental groups object to the issues being debated as part of an appropriations bill. "While it is entirely appropriate to have a lively floor debate about those funding choices, we oppose any new proposal to encumber this bill with amendments which are legislation or limitations restricting specific environmental policies," the letter reads. "Whatever the merits of any such proposals, we believe they would be more appropriately pursued through authorizing bills, regulatory procedures, or the courts."

However, Fuels for the Future made no mention as to where the five environmental groups stand on the ethanol mandate. Spokesmen for the Natural Resources Defense Council, National Wildlife Federation, and Environmental Working Group say their groups have no official position on the use of ethanol in reformulated gasoline. Attempts to contact Friends of the Earth were not successful.

The fifth group signing the letter, Sierra Club, has been against the mandate since it was issued. "We see the program as potentially increasing global warming, increasing smog, and increasing air toxics above the levels achieved by the existing reformulated gasoline program," says A. Blakeman Early, Sierra Club's environmental quality program director. "This is a clear example of politics replacing sound policy," he adds.

As for the amendment, it was defeated in a 51 to 50 vote, with Vice President Al Gore casting the tie-breaking vote.

The Clinton Administration clearly stated its position on the ethanol mandate before the vote. In a letter to Senate majority leader George J. Mitchell (D.-Me.), President Clinton said: "I am clearly aware of the attempts by some in Congress to block implementation and enforcement of EPA's rulemaking on renewable oxygenates. I strongly oppose any attempts to interfere with EPA's implementation or enforcement of this rule."

An outside, but by no means neutral, party in the ethanol mandate debate is the automobile industry, led in the U.S. by Chrysler, Ford, and General Motors. All three are opposed to the mandate, but not because of ethanol specifically.

"We are in full support of the formulation, the production, and the use of reformulated gasoline," says Jim Spearot, department head for fuels and lubricants at GM's R&D center in Warren, Mich. The company can design cars to utilize MTBE, ethanol, or ETBE.

He maintains that GM has tried to stay out of the oxygenate argument. "We didn't take sides one way or the other, but indirectly, we support the oil industry position. Our main problem with the whole EPA action in regard to renewable oxygenates is the issue of mandates. Generally, we are a company that supports free-market activities, just as we don't want to see certain types of vehicles mandated."

Says Ronald Peltier, principal research engineer at Ford: "As an industry, the automobile industry has tried to remain neutral in the oxygenate type controversy, but as a company, we have publicly stated that we don't think mandates are proper."

A spokesman for Chrysler says it will meet the guidelines for any fuels as set forth by EPA and the fuel industry.

But as is the case with many of the issues surrounding environmental regulations, new developments stemming from further research and debate could lead to revised, and possibly improved, regulations that satisfy all parties involved. ☐

Oxygenated fuels program affects many urban areas of the U.S.

Alaska
Anchorage
Fairbanks

Arizona
Phoenix
Tucson

California
Chico
Fresno
Los Angeles-Anaheim-Riverside
Modesto
Sacramento
San Diego
San Francisco-Oakland-San Jose
Stockton

Colorado
Colorado Springs
Denver-Boulder
Fort Collins-Loveland

Connecticut
Hartford-New Britain-Middletown

New York
New York metropolitan area, including northern New Jersey
Syracuse

North Carolina
Greensboro-Winston-Salem-High Point
Raleigh-Durham

Maryland
Baltimore

Minnesota-Wisconsin
Minneapolis-St. Paul

Montana
Missoula

Nevada
Las Vegas
Reno

New Mexico
Albuquerque

Ohio
Cleveland-Akron-Lorain

Oregon-Washington
Grant's Pass
Klamath County
Medford
Portland-Vancouver
Seattle-Tacoma
Spokane

Philadelphia-Trenton-Wilmington metropolitan area

Texas
El Paso

Utah
Provo-Orem

Washington, D.C., metropolitan area, including Maryland and Virginia suburbs

Source: Environmental Protection Agency

German Chemical Industry Welcomes Evidence Of Economic Improvement

■ ***Industry group president Becker sees profitability up in 1994—as a result of higher sales, lower costs, and a better attitude***

Patricia L. Layman, C&EN London

The German chemical economy is finally seeing an improvement after suffering through an abysmal 1993. First-half figures for chemical sales and production are up substantially from last year's first half. And forecasts for the rest of the year indicate continuing growth.

Last year was dismal for both the chemical industry and the overall German economy. In western Germany, overall demand and production for all products fell almost 2%, and gross domestic product (GDP) for the entire country was down 1.25% from 1992, according to statistics from the Economic Survey on Germany for 1993–94, recently published by the Organization for Economic Cooperation & Development (OECD).

The chemical industry was even harder hit. Output was down 3% from 1992 in the 11 states making up the former West Germany and down 5.2% in the five states of former East Germany.

Gert Becker, president of the chemical industry association, Verband der Chemischen Industrie (VCI), and chairman of chemical producer Degussa, said in January: "Nineteen ninety-three turned out to be the most difficult year for the German chemical industry in postwar history."

This year has brought a turnaround for the industry. Chemical sales in western Germany in this year's first half rose 4.2% over last year's first half to $53.3 billion. Through May, sales in eastern Germany were up 3.9% to $1.73 billion.

Production also improved in the first five months of this year. Volumes produced were up 5.1% through May in western Germany, and up 15% in the eastern states. At least one forecast predicts that overall chemical production will grow 3 to 4% per year this year and next, and OECD predicts that Germany's GDP this year will grow 1.75% and accelerate to 2.5% growth in 1995.

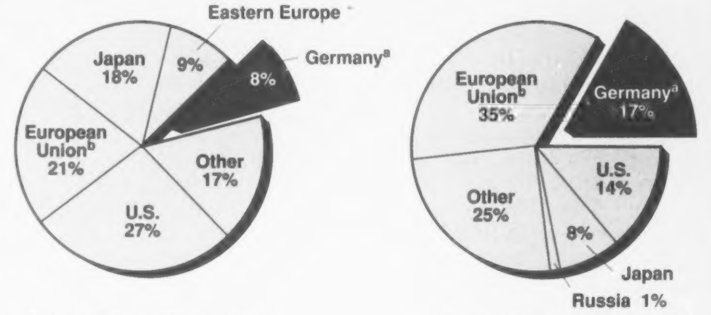
Germany's chemical industry is clearly a world star. According to data compiled by the European Chemical Industry Council (CEFIC), the German industry's sales were worth $98.7 billion in 1993, following only those of the U.S., at $314 billion, and Japan, at $208 billion. And the country fields the world's three largest chemical companies—Hoechst, BASF, and Bayer.

There frequently has been just a hint of smugness in European news stories observing the difficulty of German chemical companies in learning the lessons their international counterparts had to learn in earlier years. Those lessons, in fact, have spurred a joint position paper—issued earlier this month from VCI and from the main chemical labor union, IG Chemie-Papier-Keramik, and sent to leading German politicians—to argue for the reinforcement of the competitiveness of Germany's chemical base.

Competitiveness is now the key issue—and the German chemical industry is addressing the issue thoroughly. One result has been cutbacks in the number of employees in the industry. In 1993, the number of employees in the chemical industry declined almost 5%, to about 556,000—some 29,000 jobs were lost over the course of the year in western Germany. The eastern German chemical industry, meanwhile, employed about 44,000 people at the end of last year—29% fewer than at the end of the previous year. Productivity in the eastern sector, according to Becker, is still only half that of the western German level, so more rationalization measures will be needed.

Since Becker's comments in January, however, things have begun improving. Now, nine months into the year, Becker, in an exclusive interview with C&EN, points out that "some improvements have taken place since the beginning of the year. The economy is improving—sales and volumes are up 4% in the first

Germany has 8% of global chemical sales, 17% of exports



Total 1993 world chemical sales = $1.17 trillion

Total 1993 world chemical exports = $310 billion

a Both eastern and western sectors. b Excluding Germany.
Sources: Verband der Chemischen Industrie, C&EN estimates

six months." Perhaps more important, he adds, "Profitability is up significantly, mainly due to structural redesigning of German chemical companies."

Even beyond those financial measures, however, he sees "an improvement in the psychological environment. We have the feeling that politicians and the public are more and more aware of Germany being increasingly involved in a global competition. The politicians themselves are challenged now to improve the competitiveness of the German nation in every respect.

"These soft facts," he points out, "along with the hard facts of sales and production, definitely can be defined as an overall improvement. Crises can have many good effects, once they are used to bring changes that were unimaginable before."

Some examples: cutting the number of employees and demanding more work for the same salary. The economic crisis, he suggests, is "challenging companies, including German chemical companies, to consider Germany as a 'standort' "—as an industrial base, or country, in which one can do business—"that will maintain its competitive position in the worldwide community, and in worldwide trading."

Moreover, although the economy is improving, Becker says, "changing the structure of the German chemical industry must go on." In many respects, of course, that is easier said than done, because the German industry is "characterized by fully integrated chemical processes. From the beginning, the goal of companies was to find a use for every by-product. Therefore, chemical plants in Germany have been engineered in such a way that one product would find a use across the plant.

"This was of great advantage for the German industry when economic activity was high," Becker says. "But now, imports of basic chemicals and those with higher added value coming from developing countries and China, in particular, are having a dramatic impact on the structure of the German industry. A certain dislocation of products will take place. No longer will every product or every intermediate be produced here. We will have a production network in Europe, in the U.S., and so on, combining our technologies in a way so they are not all here in Germany. This is costly," he points out.

Becker: our industry has done its homework

Costly, but necessary, forced by two major developments. The first is the need for the industry to penetrate markets far away from Germany, to be global. "We must bring production to the markets—you cannot serve them from here, given transportation costs and risks," Becker observes.

The second development is the changing of cost structures. "Costs in Germany have increased dramatically," he notes. "To remain competitive, we must transfer production to countries where production costs are lower than here."

Underlying that trend, he adds, is that the volume of products and sales from German plants is not growing as fast as those outside Germany. "But the administrative costs for running an international chemical company are still here in Germany—central research, central engineering, and so on. The management of a company with its affiliated services, such as accounting and legal, all remain based in Germany, with an increasing volume of costs. The volume of sales to cover these costs is stagnating. The logical conclusion is that we must transfer some of these central costs to where the sales are available to absorb them."

Not all central functions will be split out, he predicts. For example, "I think central research activity will remain in Germany. One of the advantages of the German standort is that we have powerful R&D institutions, with a permanent flow of highly educated scientists. Without any doubt, this is a great advantage for the chemical industry. We will use these scientific potentials as long as possible. But research operations closer to technical assistance or development will be brought closer to the marketplace," he predicts.

For the German chemical industry, however, "the scientific potential is useless if we cannot transfer an idea to product or to technology. If legislation and bureaucratic processes in Germany will not be adapted to the new challenges, the potential we have in Germany will not come to any significant effect. Then the young scientists will go to the places where their ideas will be realized."

A recent article in *Chemie Report*, published by VCI, noted, among other points, that in the field of technology the German chemical industry has had considerable advantages to date, "but this competitive edge is now seriously threatened. Many technologies are today available worldwide and no longer offer a competitive advantage in Germany. And the aggravating factor is that, due to numerous institutional obstacles, the implementation of new technologies takes too much time."

One of the most controversial areas of research for the country's industry is in the biotechnology field. For years, the German chemical and pharmaceutical industries have been lobbying for modification, at the least, of some of the more restrictive regulations regarding biotechnology and genetic research—with mixed success.

In the genetics field, Becker says, "quite a lot of brilliant young frustrated scientists decided to leave Germany and go where the climate is more favorable. This remains a major task for VCI—to speed up all the bureaucratic processes for transferring innovation from labs to production units and to markets.

"We have succeeded in adapting the legal framework for genetic technology to the European level—German legislation has been normalized in line with European legislation. But that still lags significantly behind the U.S. and Japan," Becker says.

The inflexibility of the German legislative process is one of the points mentioned in the position paper written earlier this month by Hermann Rappe, head of IG Chemie, and VCI's Becker. The position paper addresses "the current state and future of the German chemical base—protecting the environment and safeguarding the industry."

The paper presents ideas and proposals to Chancellor Helmut Kohl and other leaders of the governing and opposition parties. The proposals are intended to "help to jointly find new solutions and bring about their realization in this new legislative period," says a VCI statement.

Among the points made is that "a deeply felt change of values in society has reduced the acceptance of innovations. Subjectively perceived risks outweigh the view that industry and technology create the chances that are the source of wealth."

The paper argues, among other things, that the innovative capability of the German chemical industry "must be strengthened. This above all requires the removal of the existing hurdles to innovation in both the legal and administrative areas. New products and new technologies create replacements for products that are no longer profitable and thus secure employment. Technological advances must be created, built upon, and maintained.

"All those who carry responsibility in politics, the economy, and the sciences must strive hard to strengthen the willingness in our society to once more innovate and change." The paper's authors see the challenge as exceedingly serious: "The German chemical industry is fighting for its international competitiveness, and the clawing back of this position requires a joint effort by the employers, the work force, and the state. Additional burdens cannot be borne under any circumstances—that also applies to the currently much-discussed eco taxes."

The last phrase is the only mention of the carbon tax, or tax on carbon dioxide emissions, in the position paper. But the subject is high on the political agenda in Europe and is fiercely resisted by chemical industry executives there. For example, Jürgen Strube, chairman of BASF, has warned of serious consequences for the country's industrial base if its politicians adopt such an energy tax. "Important [industrial] sectors would have to be relocated abroad, the figures for the economy as a whole will deteriorate, and jobs within German industry will be severely jeopardized," Strube says.

According to Becker, the tax has become a particularly hot political issue because of the country's upcoming elections, scheduled for October. "After October, we may come down to Earth again. The carbon dioxide tax and redesigning of the German tax system to reward ecological steps forward and punish those who hurt the ecology sound very nice—but are very theoretical. In practice, it would be very difficult.

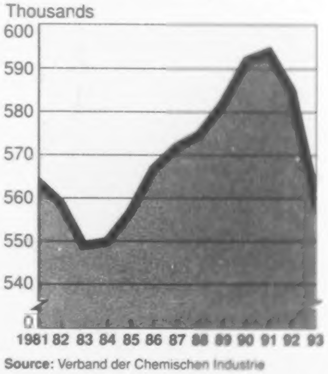
"We will have to talk about this after the elections," he says. "Of course, a carbon tax would punish in particular the German chemical industry, and the result could well be that production with higher carbon dioxide emissions would be transferred to countries with less stringent regulations. Overall, it would not decrease emissions. But in Germany, it would result in loss of jobs, tax revenues, and sales—to cover our central costs."

Becker has noted a change in political and public perception of the chemical industry. He has also noted, and is encouraged by, German chemical companies' changing attitudes toward the public.

"The public has realized that we need chemical operations in Germany, that they are an essential part of the German industry, that the chemical industry is creating jobs and catalyzing innovations. But German companies realize more and more that fears among neighbors and citizens have to be accepted as facts. This feeling is now spreading over the management boards," Becker believes.

One sign of the changing times is that for the first time in the industry's history, major chemical companies are being run by people without a scientific background—by those with a background in economics, law, or marketing, for example. Becker, who started on the commercial side of Degussa 40 years ago, eventually becoming its chairman, says, "I wouldn't say that has triggered a change of mind, but it has triggered public opinion that change is taking place."

Employment drops 5% in western Germany in 1993



Source: Verband der Chemischen Industrie

Among the major issues on his agenda during his presidency of VCI, Becker wants to "emphasize public relations—talk with the public, so it recognizes and accepts the need for the chemical industry to continue to exist," he says.

"We want to make visible to the public that the chemical industry provides the German nation not only with income and exports delivering hard currency but also with innovations, which are necessary to secure the welfare not only of Germany but also of a growing world population. The chemical industry can provide the keys to make the gap between the richer and the poorer in the world narrower." As one example, he cites providing the agricultural sector with plant protection products and with newly developed technology to increase yield, via genetics, to avoid opening up new land for agricultural production—thereby reducing emissions of carbon dioxide.

"We must make clear that the chemical industry has the greatest potential to provide humankind with solutions to feed the population, to protect the environment, and to fight diseases. This is my major point during my two years."

If the industry can do that, he predicts, it will lead to pressure on government and local authorities "to be even more helpful, to support us to continue to be here, to develop new products, and to see that those are developed to generate new jobs and income." It may also help attract young people into the chemical industry. "They will be attracted if they get the feeling they can contribute solutions to the world problems. We are the ones who can make the real contributions, and we need their help. Then they will not shy away from studying chemistry and joining the chemical industry."

According to Becker, "I would like to see the message get across that the German chemical industry has done its homework under the pressure of the crisis. There is still a lot that has to be done, but results so far achieved are increasing our confidence that the core of chemical activity of German chemical companies will remain here.

"If the present process of cutting unnecessary costs, streamlining legislation, and removing unnecessary legal burdens will continue, we can be quite optimistic about the future of the German chemical industry. Optimism is much more creative than pessimism." ☐

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CHEMICAL & ENGINEERING NEWS

C&EN

OCTOBER 3, 1994

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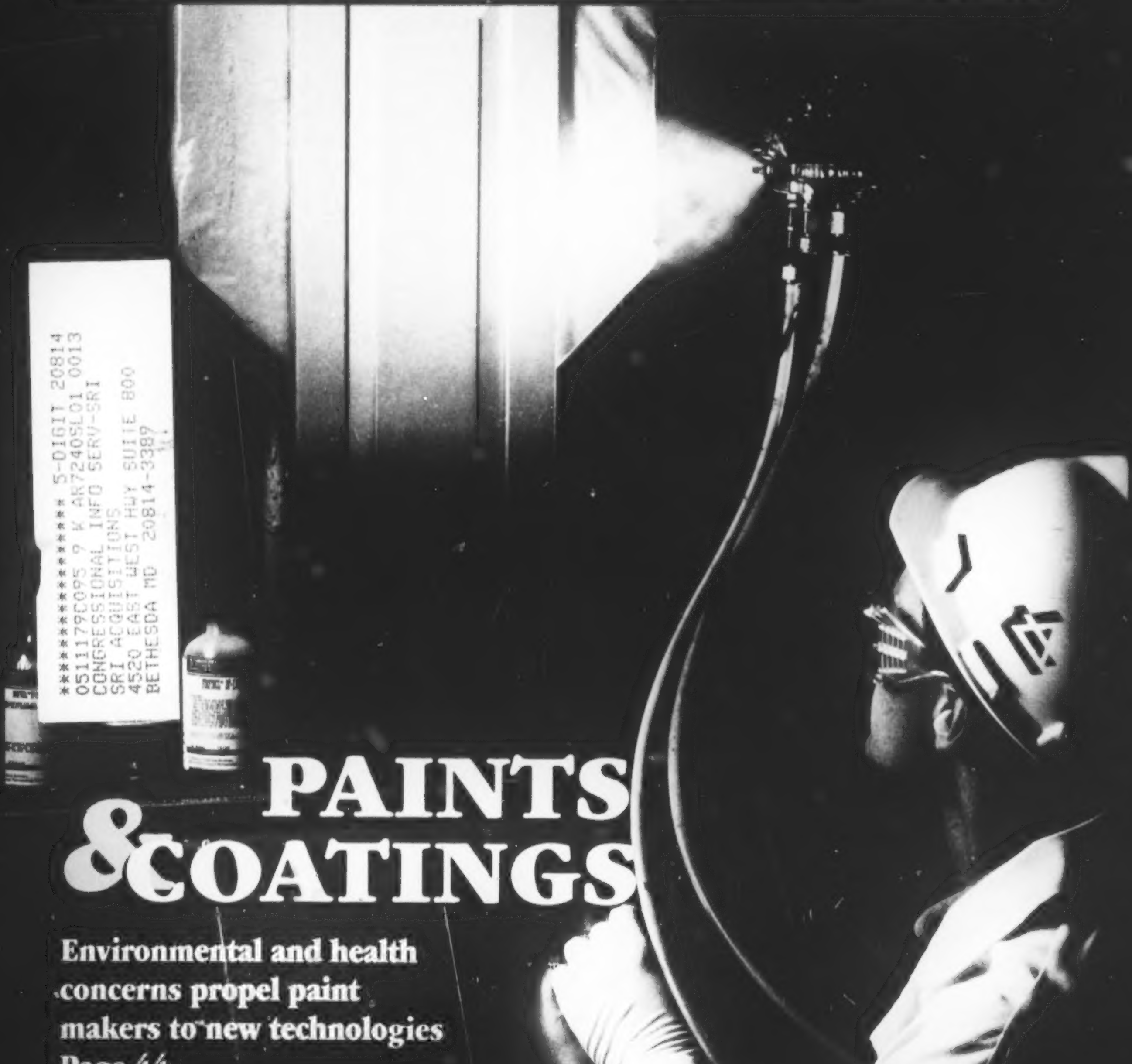

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PAINTS & COATINGS

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1155—16th St., N.W., Washington, D.C. 20036
Editor: Michael Heylin (202) 872-4501
Managing Editor: Madeleine Jacobs
Assistant Managing Editors: Rudy M. Baum, Ernest L. Carpenter, Janice R. Long, Rebecca L. Rawls, William J. Storck
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News Bureaus: Northeast: (908) 906-8300 Ann M. Thayer (Head), Elisabeth Kirschner (Assistant Editor), George Peaff (Assistant Editor), Rachel Eskenazi (Administrative Assistant). Houston: (713) 558-2912 Susan J. Ainsworth (Head). Washington: (202) 872-4495 David J. Hanson (Head), West Coast: (206) 517-5034 Deborah L. Illman (Associate Editor). London: (01) 44 81 870-6884 Patricia Layman (Senior Editor), (01) 44 256-811052 Michael Freemantle (Senior Editor)
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LETTERS

Supply-and-demand equation

I would like to commend Attila Pavlath on his poignant commentary (C&EN, Sept. 12, page 46). As a recent Ph.D. graduate in inorganic chemistry of a well-respected school, I have given up after more than a year of fruitless job hunting, networking, hustling, even begging and pleading to be given a chance to work in a lab. I know I am not alone in what some have called the worst job market in 20 or more years.

During all of my undergraduate and most of my graduate school years, the American Chemical Society, the National Science Foundation, the Department of Labor, and other authoritative agencies claimed a "critical national shortage" of chemists and other technical people. In analogy to Pavlath's equation, this would be a case of $2 + 2 = 3$. Attempts to make the equation equal involved the heavy and much-publicized recruitment of young and intelligent men and women into science. During this same time, much of industry saw the equation as being $2 + 2 = 5$ and systematically downsized R&D. Academicians in universities were too busy writing grants and arguing over the mechanisms of addition and wondering how the equal sign works to notice any problem.

When combined, these three factors created a generation of young and highly trained scientists who either work like slaves in temporary postdoctoral positions or work in constant fear of whether the next paycheck will include "walking papers." The scientific community has created a very unhealthy situation for itself, which inevitably will ruin chemistry and science as a profession. Now is the time for ACS membership to take an active and leading role in resolving this problem. Failure to act now will only mean that the national meeting in the year 2020 will have to be held in a geriatric ward.

Carter White
San Diego

Influence of George Hammond

I was delighted to read that George Hammond has been chosen to receive the National Medal of Science. When I was a graduate student at Iowa State (1950–53) and he was a young faculty member, he had more of an influence on me than anyone other than my thesis adviser. His course on organic reaction mechanisms gave me, for the first time, an understanding of what organic chemistry is about. More to the point, he taught me to see chemistry as a unified subject, not a set of loosely related specialties. I still remember a chemistry department seminar he gave with the title, "We all wash dishes." It was, no doubt, the main reason that I managed to do research in physical, analytical, clinical, and biochemistry. I can't imagine a better career.

Marvin Margoshes
Tarrytown, N.Y.

Bricker, antibiotic analysis

Notice of the death of Clark Bricker (C&EN, Aug. 1, page 54) brought back the memory of his contribution to an analytical method for the quantitative spectrophotometric determination of solutions containing both of the antibiotics chlortetracycline (Aureomycin) and tetracycline (Achromycin).

I was in an analytical development group at Lederle Laboratories when tetracycline was synthesized by hydrogenating chlortetracycline, which was produced by a fermentation process. Individual solutions of chlortetracycline and tetracycline in concentrated sulfuric acid containing boric acid showed blue and red colors, respectively, to the eye (I may have the colors reversed—this took place more than 40 years ago). However, spectrophotometric curves showed absorbance maxima at wavelengths that were too close to allow two-component spectrophotometric determinations of solutions that contained both chlortetracycline and tetracycline.

Correction

- Sept. 19, page 12: Alberta & Orient Glycol (a joint venture of Union Carbide, Mitsui & Co. of Japan, and Far Eastern Textile of Taiwan) has ethylene glycol capacity at Red Deer, Alberta, Canada, of 660 million lb per year, not 1.3 billion lb. Union Carbide is the sole owner of another ethylene glycol unit with a 660 million-lb capacity at the same site.

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Agricultural Chemical Producers Rebound From Floods Of 1993

■ ***Increased acreage, higher prices, and drier weather are spurring bumper sales of more and safer products with improved packaging***

Elisabeth M. Kirschner,
C&EN Northeast News Bureau

Agricultural chemicals make up a nearly mature market, growing at about 4% per year in the U.S. However, this year is one of the better years in recent memory.

In response to higher cotton prices and summer floods in 1993, U.S. acreage—and the agricultural community's pesticide needs—has increased for the 1994 season. This year's more benign weather conditions and new products also contributed to the often impressive rise in demand for agricultural chemicals. Zeneca Ag Products president Bob Woods says his company's North American sales were up 23 to 25% over 1993's depressed figures.

But the business of pesticide producers is shifting under grower, consumer, and government demands. Safer chemicals and application technologies, as well as biological products, are increasing sales figures even as they bring volumes down. Herbicides, which gained in importance with the advent of soil-saving no-till farming, have been at the forefront of pesticides' growth in demand.

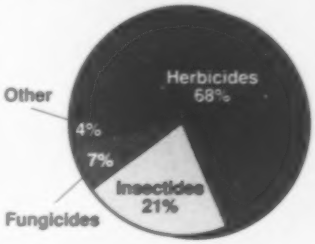
In this highly global industry, the U.S. accounts for about 24% of worldwide pesticide consumption by volume, but 34% by sales. And the U.S. has a positive trade balance in this market. Industry estimates of 1993 exports totaled $2.08 billion, with imports reaching $1.36 billion.

Europe—normally accounting for about 25% of global demand—saw pesticide use drop in the past two years, says John McDougall, analyst at Wood Mackenzie Consultants, Edinburgh, Scotland. Under the European Union's Common Agricultural Policy reform, which reduced government supports for cereal production, acreage decreased nearly 15%, he says. Growth should increase in developing countries, McDougall predicts, as industrialization takes workers off the farmland and international trade accords kick in.

Worldwide, Ciba led 1993 sales with $2.77 billion, according to McDougall, followed by DuPont ($2.02 billion), Monsanto ($1.94 billion), Zeneca ($1.89 billion), Bayer ($1.70 billion), and Rhône-Poulenc ($1.68 billion). And, he says, the Hoechst-Schering crop protection joint-venture AgrEvo established last year would have accounted for nearly $2 billion in sales if the venture had been in operation for the entire year.

Compounding slow growth rates, the agricultural chemical industry also faces new costs from increased regulatory burdens. The Environmental Protection Agency has required producers to renew registrations on old pesticides to meet newer and stricter testing requirements. Phil Calderoni, business manager for pest control consulting at SRI International, Menlo Park, Calif., says the program encourages companies to drop the more toxic pesticides without necessitating an EPA ban.

Herbicides make up bulk of U.S. pesticide sales



Total 1993 pesticide sales = $6.8 billion

Source: American Crop Protection Association

But most drops in pesticide use are tied to economic considerations, says Zeneca's Woods. Zeneca has licensed products to other companies and dropped some minor uses—crops other than corn, soybeans, wheat, and cotton—because sales would be insufficient to offset reregistration costs. "We've spent $100 million to $150 million on reregistration," says Woods, with none of that going toward improving sales.

Meanwhile, developing a new pesticide can take sev-

DuPont photo

Increases in major crop acreage, such as corn, and better weather conditions have helped improve U.S. pesticide sales this year.

American Crop Protection Association photo

Application volumes have dropped as toxicity and specificity increase with new pesticides.

en to eight years, says Calderoni, with costs averaging $50 million. That, he says, as well as the competitiveness of the industry, has prompted consolidations such as AgrEvo to offset the costs of R&D, testing, and marketing.

In June 1993, EPA, the Department of Agriculture, and the Food & Drug Administration announced the Integrated Pest Management Program (IPM), which aims to reduce risks from agricultural and nonagricultural uses of pesticides. Although the initiative is expected to cut pesticide volumes, EPA's director of biological and economic analysis division, Allen L. Jennings, says that that is not the main goal. "We try to look at risk," he says, "which is a whole lot more than measuring pounds." Some options include smarter use of existing conventional pesticides, alternative technologies, and practices that reduce risk. This month, EPA plans to announce the first commodity-specific risk reduction plans developed by pesticide users. EPA's goal is to enroll 75% of agricultural acreage in IPM programs by 2000.

In the same vein, EPA has also implemented a reduced risk pesticide policy to streamline and speed registration for products that are safer than those now in use to get them to market sooner. Of 11 products proposed, six have been accepted for faster registration, and one—DowElanco's hexaflumuron termiticide—has already been accepted for registration, says John McCarthy, vice president of global scientific and regulatory affairs of the American Crop Protection Association (ACPA), Washington, D.C., formerly the National Agricultural Chemicals Association.

That shows the industry has been working toward safer technologies and IPM for years, says McCarthy. "The products that we see today were discovered eight to 10 years ago." Agricultural chemical companies are improving the molecules, using integrated approaches including biological control agents and genetic engineering to create insect- and disease-resistant plants, he says.

The name change to ACPA "captures the potential of today's biological and bioengineered products," says ACPA president Jay J. Vroom. For 1993, members reported $4.25 million in sales of *Bacillus thuringiensis* and other biologicals, compared with $6.8 billion in total sales of pesticides. A report from the Cleveland-based industry consultants, the Freedonia Group, predicts that biological pesticides will grow 19% per year through 1997.

The greatest pressure appears to be on atrazine herbicides, the largest volume pesticide, which EPA estimates reached 70 million to 75 million lb in 1993. Atrazine faces challenges because of its toxicity and potential for groundwater contamination. Other products, such as organophosphates and carbamates, face replacement because of insect resistance.

"There are terrific opportunities for new technologies to replace older ones," says DuPont agricultural products vice president William F. Kirk. DuPont has target-specific products as well as product systems under development, he says. In waste reduction, the company goal is to reduce packaging materials 50% by 2000 through technologies such as tablets and water-soluble film containers. Last month, DuPont opened a grain biotechnology R&D center in Urbandale, Iowa. Although traditional pesticides have increased acreage value by limiting pest damage, DuPont's grains strategy is to increase the amino acids or oil content of each plant to increase the sale price of each bushel.

American Cyanamid is the fastest growing agricultural chemicals company according to McDougall. Ken Sekley, Cyanamid's marketing manager for retail distribution, attributes much of the company's double-digit growth in 1994 to the imidazolinone herbicides, which work at a level of 2 to 4 oz per acre compared to pounds per acre for older herbicides. Imidazolinone-tolerant corn has increased the herbicides' use this summer, adding to sales for soybean protection.

Cyanamid has also formed an alliance with Sandoz, copackaging imidazolinones with Sandoz herbicides for broad-spectrum weed control in soybean and corn crops. The company hopes to introduce another member of the imidazolinone family for broadleaf weed control in peanuts next year. With the expected change of corporate ownership, Sekley stresses the company's plan for continuity.

Rhône-Poulenc is working with agricultural biotechnology firm Calgene to develop a genetically engineered cotton that can tolerate its Buctril bromoxynil broadleaf herbicide. A company spokesman says that application after the crops emerge can reduce the number of applications and overall chemical use. The company is also banking on its fipronil insecticide, Regent, with a possible 1997 introduction for corn protection, to replace pyrethroids that have come up against resistant insects. Rhône-Poulenc is also beginning to license its gel technology for packaging pesticides. When a water-soluble pack is loaded into an applicator tank, the gel disperses in less than a minute, says the spokesman.

DowElanco is another product of consolidation in the industry, creating a critical mass for R&D. The company spends more than 10% of annual sales—which totaled $1.6 billion in 1993—on R&D. DowElanco's hexaflumuron termite-colony elimination system and a fermentation-derived insecticide are in the works. In the high-growth herbicide area, the company is expanding markets for its low-dosage flumetsulam product, Broadstrike. The herbicide, which has an application rate of teaspoons per acre, also has low toxicity, he says, because it interacts with an enzyme not found in people.

Zeneca's paraquat herbicides have continued to grow with the increasing no-till farming practices that minimize soil erosion. And Zeneca is submitting its new alkyl ester fungicide—with its broad spectrum of uses and low environmental toxicity—for fast-track registration in 1995, says Woods.

Monsanto and Zeneca together received registration for acetochlor earlier this year. Acetochlor promises decreased herbicide volumes and lower carcinogenicity than existing corn herbicides. But because of toxicity concerns, the registration contained an unusual provision for revocation should residues leach into groundwater or herbicide volumes not decrease according to estimates. Sales have been "pretty good," says SRI's Calderoni.

Monsanto purchased the Ortho business from Chevron last year and is considered a likely partner or buyer of American Cyanamid's agricultural chemicals business should it be split off for sale. Monsanto has been developing a new low-use halosulfuron, with applications to be measured in fractions of an ounce per acre. Sulfonylureas, which include inhibitor functional groups on the molecule that can only be removed by certain insect enzymes, keep the toxic properties from being realized in other animals. Monsanto has also been developing crops resistant to its broad-spectrum glyphosate herbicide, Roundup, one of the "cash cows" of the industry. A Monsanto spokesman says a tolerant soybean hybrid is close to commercialization, and the company is also pursuing resistant corn and canola with seed companies.

Ciba is focusing on safer, more selective IPM-compatible products. They are more complicated molecules, says Don Allemann, manager of insect control research, with chemistries that vary widely. "The more you ask of a compound usually the more complicated it gets," he says. The newer entries are also much more active, requiring less volume. The company has concentrated considerably over the past five to six years on biologicals, he says, which may yield modest niche products. "We're not losing our focus on chemistry," he says. "Consumers want blemish-free fruits and vegetables, but they don't want any chemical residue." Using chemicals early in the season and biologicals later could solve this paradox, he says.

But no matter what the changes are in pest management, says McCarthy, "synthetic chemistry is still the backbone" of crop protection. ☐

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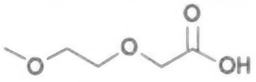

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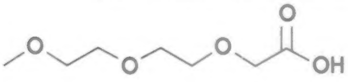

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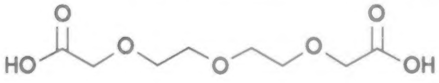

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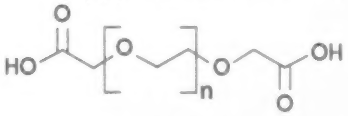

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Biotech industry readies for reform and renewal

After surviving recent difficult economic and political developments, the biotechnology industry is preparing for a turnaround. In the past 12 months, biotechnology companies have faced pressures emanating from the health care reform debate while watching capital markets shrink and potential major pharmaceutical partners undergo consolidation. But double-digit growth for most biotechnology industry measures and a strong outlook for new products are leading to expectations that biotechnology companies are reorganizing themselves in preparation for a reemergence.

These are some of the major conclusions in Ernst & Young's ninth annual report on the biotechnology industry, "Biotech '95: Reform, Restructure, Renewal." The New York City-based accounting and professional services firm developed the industry outlook after surveying nearly 400 biotechnology chief executive officers.

Overall, the biotechnology industry continued to show growth for the fourth consecutive year. Revenues rose 12%, to $11.2 billion, for the fiscal year between July 1993 and June 1994. Product sales accounted for 69% of all revenues—the remainder came from contract and collaborative R&D funding, licensing, royalties, and other income. Just 10 leading products had combined sales of $4.3 billion during the 1993 calendar year.

Despite the growth in sales and revenues, the industry still reported a net loss of just over $4 billion, up from a loss of $3.6 billion for the previous 12-month period. An increase in overall spending contributed to the loss. Much of the outlays went into R&D spending, which grew by 23% to reach an industry total of $7 billion.

Public companies, which numbered 265 this year, contribute disproportionately to overall industry results. Revenues rose 18% for this sector, to $7.1 billion, and product sales were up 21%, to $5.2 billion. But the combined net loss of this sector grew to $2.1 billion from $1.5 billion the previous year. Among public companies, R&D spending rose 27% to a combined $3.8 billion.

The industry's year was not without its major challenges, particularly because of tightness in capital markets. The 1993–94 period was the first time in the industry's history that the number of startup companies declined. Startups dropped to 13 from 57 the year before and from an all-time high of 119 in 1987. The number of new companies formed was also the smallest since 1973, when there were only six.

The increased spending rate has led Ernst & Young to adjust its survival index—a measure of how many months of cash a company has left. At current spending levels, the median survival index for public companies has fallen to 25 months from 34 months last year. Less than a quarter of the companies are reported to have enough cash to survive for five or more years, and about 26%, up from 17% last year, have enough cash for less than one year of operation.

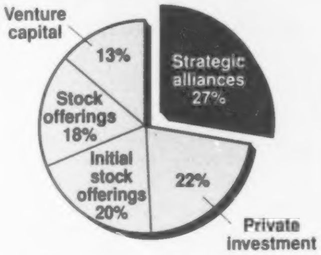
To survive, many companies are expected to refocus and reorganize their operations while continuing in the ever-constant hunt for cash. A total of $4.7 billion was raised by biotechnology companies between July 1993 and June 1994, a 17.5% increase over the previous year. Although funding was up, the number of deals made has dropped steadily in the past few months.

Most biotech measures grow, including net loss

	Public companies			Industry total		
$ Billions	1992–93[a]	1993–94[a]	% change	1992–93	1993–94	% change
Product sales	$ 4.3	$ 5.2	21%	$ 7.0	$ 7.7	10%
Revenues	6.0	7.1	18	10.0	11.2	12
R&D spending	3.0	3.8	27	5.7	7.0	23
Net loss	–1.5	–2.1	40	–3.6	–4.1	14
Market capitalization	39.0	36.0	–8	45.0	41.0	–9
No. of companies	235	265	13	1,272	1,311	3
No. of employees	48,000	53,000	10	97,000	103,000	6

a Fiscal years from July 1 to June 30. **Source:** Ernst & Young

Most capital is raised by forming alliances



Total 1993–94[a] biotechnology industry financing = $4.74 billion

a Based on fiscal year from July 1 to June 30.
Source: Ernst & Young

Financing through stock offerings became more difficult in the second quarter of 1994 and has continued to be so in the third quarter. The result has been a declining market value in the first nine months of 1994 for 82% of public biotechnology companies. For the period between July 1993 and June 1994, the market capitalization of the public companies dropped to $36 billion, from the previous year's $39 billion, although the number of companies rose by 30.

"While Congress continues to disagree over the contents of a health care bill, the dialogue alone may have served to accelerate market changes already in progress," says G. Steven Burrill, senior adviser to Ernst & Young. "Political reform's greatest impact has been to create higher levels of uncertainty that haunt the biotech industry in the financial markets."

But Burrill and his coauthor on the report, Kenneth B. Lee, national director for Ernst & Young's Life Sciences Industry Service, are optimistic that the changing health care market will accept innovative biotechnology therapies and products and understand their relative costs and benefits. A few new products approved last year—such as Genentech's Pulmozyme, Genzyme's Cerezyme, and Chiron's Betaseron—and others poised for approval in the coming year should add greatly to the performance of the industry. Major pharmaceutical producers are expected to continue to find biotechnology companies attractive partners for new product development, despite consolidation among the big companies.

Ann Thayer

Survey shows public support for U.S. manufacturing performance

Just what does the American public think of industry and especially manufacturing? In these days when television programs are replete with greedy corporate executives, polluting manufacturing companies, and shoddy, if not illegal, manufacturing practices, the question is a fair one. And it is a question that the National Association of Manufacturers (NAM) sought to answer in a survey of the public and Washington opinion leaders.

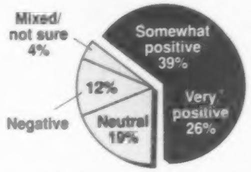
The answer, it turns out, is somewhat surprising, although certainly not unpleasing to the survey's sponsor. The U.S. public and its opinion leaders overwhelmingly approve of the job being done by U.S. manufacturing, according to the survey conducted by Peter D. Hart Research for the Manufacturing Institute, an education and research affiliate of NAM.

The responses show that 63% of the public surveyed approve of the way that manufacturing is doing its job, with only 27% disapproving. This ties with the survey ratings for approval of the performance of colleges and universities. In fact, all segments of industry score high in the approval ratings. Besides the strong support for manufacturing, 61% of the respondents approve of the performance of U.S. industry as a whole and of the performance of employers as well.

In fact, the only institutions included in the survey that do not get firm support for their job performance are Congress and political parties. Only 34% of the respondents approve of the job that Congress is doing, with 59% disapproving. And only 29% approve of the performance of political parties, with 62% disapproving.

The survey included interviews among a random sample of 751 adults nationwide, as well as 526 Washington opinion leaders—which included members of Congress and its senior staff, top executive branch officials, and members of the media—who returned a questionnaire they had been sent.

Manufacturing has a 65% positive rating



Source: National Association of Manufacturers

While 63% of the public respondents approve of manufacturing performance, among opinion leaders, the approval rating is much lower, with 51% approving of job performance and 13% disapproving.

In another area of the poll, about two thirds of the public express positive feelings about manufacturing, with 26% being very positive and 39% being somewhat positive. But, here too, differences do exist between the attitudes of the public and those of opinion leaders. For instance, the opinion leaders have higher positive attitudes toward manufacturing than the public has, with 78% running positive and 6% negative, compared with 65% positive for the public and 12% negative.

And there is one outstanding difference between the two groups. When asked what type of company will contribute most to U.S. growth in the next five years, 58% of the public cite manufacturing, whereas 38% view service industries as most important. Among the opinion leaders, the split was almost reversed, with just 33% favoring manufacturing and 56% seeing service industries as most important. Jerry Jasinowski, president of NAM, says, "Clearly the public is way ahead of Washington in understanding manufacturing's key role in our economic future."

Public approves of how industry does its job

	Approve	Disapprove
Manufacturers	63%	27%
Colleges	63	27
U.S. Industry	61	29
Employers	61	31
Congress	34	59
Political parties	29	62

Source: National Association of Manufacturers

Jasinowski further comments, "The public is also on target with regard to what the federal government should do to encourage the growth of U.S. manufacturing companies." He notes that the survey shows 78% of the public responses recommend tax breaks for businesses to invest in U.S. plants; 73% recommend reducing regulations that hinder growth; and 72% call for cost-impact studies before making policy changes.

In terms of product quality, 66% of the public believes that U.S. products have improved over the past five years, with 22% saying they have improved a lot and 44% saying they have become a little better.

The study points out that those especially likely to praise U.S. products are adults with incomes of more than $50,00[illegible] men, and young adults (ages 18–29). In these three categories, about 75% say that U.S. products had improved, while 13% or less say the product quality had declined. Among the Washington opinion leaders, 92% believe quality has improved.

Jasinowski concludes: "The survey sounds a reassuring note that the public and Washington are beginning to appreciate the importance of manufacturing to America's economic strength. Our goal is to make sure this understanding leads to better cooperation among labor, management, and government so that U.S. manufacturing can continue to excel across the board."

The support among the public for manufacturing is so strong in the survey that perhaps the chemical industry, which has been much vilified by the public, should change its name to the molecular manufacturing industry.

William Storck

PRODUCT REPORT

PAINTS & COATINGS

Government mandates, driven by environmental and health concerns, pressure industry to develop new technologies

Marc S. Reisch,
C&EN Northeast News Bureau

Paint and coating formulators had a good year in 1993, continuing the modest recovery begun in 1992. Sales rose 4% above those for 1992 to nearly $13 billion, and 1993 shipments rose more than 3% to nearly 1.1 billion gal, according to the Department of Commerce.

Preliminary figures for the first six months of 1994 indicate this year could be even stronger. But although the industry appears to be making solid advances in sales and shipments, it is racing behind the scenes to adapt to a rapidly changing regulatory scene.

The paint industry has been dealing for some time with government restrictions, such as those concerning volatile organic compounds (VOCs), precursors of lower atmospheric smog. Whenever possible, industrial paint consumers have shifted to newer technologies, such as heat-curable powder coatings and radiation-curable coatings. Both of these technologies can eliminate VOCs because they do not require the use of solvents.

Conventional liquid coatings include VOC-containing solvents that evaporate into the atmosphere as liquid coatings dry. However, radiation-curable coatings and powder coatings are only practical on specially adapted, original equipment manufacturers' product-coating lines. Conversion from liquid coatings to alternative systems can be quite expensive, so paint users are generally eager to continue using newly developed low- or no-VOC liquid coatings on their existing paint production lines.

However, the Clean Air Act of 1990 will effectively regulate liquid coatings widely used, for instance, to paint building interiors and exteriors, to maintain industrial plants and equipment, and to coat and protect furniture surfaces. The Clean Air Act will require state and local governments to develop plans, if they have not already done so, to lower regional atmospheric pollution in compliance with federal law. An element in those plans will enforce limits on VOCs emitted from liquid coatings as they dry.

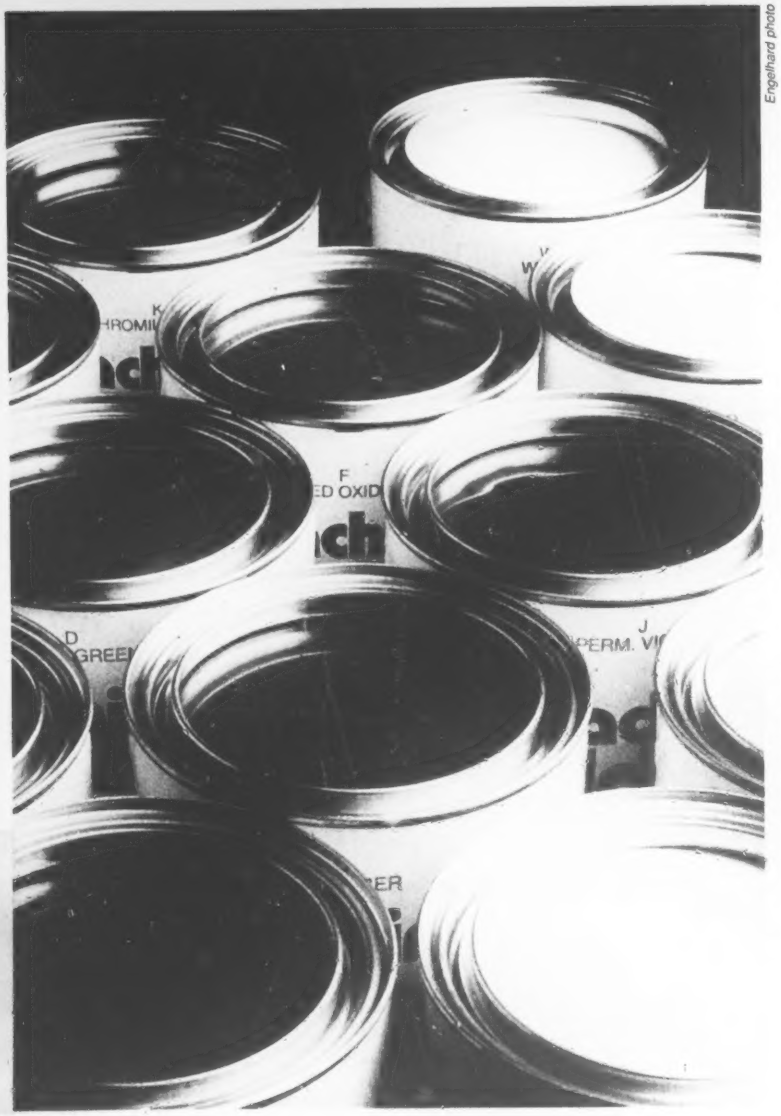
The Clean Air Act also complicates formulators' problems because the law will restrict the use of solvents considered hazardous air pollutants (HAPs). So manufacturers of liquid coatings must simultaneously meet VOC limitations and HAP restrictions.

The federal clean air mandates that affect the paint and coatings industry start to take effect in 1996. Manufacturers cannot dally if they want to sell liquid coatings in large metropolitan areas that do not meet air quality standards. As a practical matter, the law effectively forces most manufacturers to make all their liquid paints meet the strictest regulation.

The race to reformulate liquid coatings has opened up new opportunities for both paint formulators and material suppliers. Formulators who can sell paints that meet regulatory limits and still provide performance comparable with or even better than older products will have a marketing edge. Material suppliers have an opportunity to introduce new—and frequently higher priced—components that allow the production of low- or no-VOC coatings. Material suppliers thus have an opportunity to gain entry or market share even as they are introducing value-added, higher profit products into the market.

The effort to reformulate liquid coatings will also affect the market for relatively small high-performance materials. Silicone additives, used in minute quantities, give paint antifoam or easy wetting characteristics. Silicone resins—used at 20% or more by volume in a coating—add excellent weatherability and heat resistance to certain niche applications, such as for smoke stacks and barbecue grills. Other silicone formulations protect masonry from water damage.

How the manufacturers of specialty silicone materials cope with pending government regulations provides a study in the competition among the manufacturers of a particular class of material. Many silicone manufacturers, such as Dow Corning and Wacker, are making efforts to formulate their liq-



Engelhard photo

uid-coating offerings so that they are compatible with water-reducible and low-VOC systems. The silicone material manufacturers are also working to increase their market niche by reducing or eliminating the HAP solutions in which they have traditionally supplied silicones.

Paint shipments rose 3% in 1993

Paint shipments gained momentum again in 1993. According to the Department of Commerce, shipments rose modestly, a little more than 3%, following a 2% increase in 1992. Shipments in 1991 were down about 5% compared with 1990 as the industry felt the effect of a recession.

The growth of architectural coatings accounts for much of the increase in shipments. Shipments within that category rose nearly 5% to 604 million gal. The increase reflects not only a spurt in home building, but also an increase in consumer purchases. Since the economy has been recovering, more people have spent money to spruce up their homes.

Shipments of product coatings—which are used by original equipment manufacturers to protect automobiles, appliances, metal furniture, and other products—rose nearly 3% in 1993 to 321 million gal. Much of the increase in this category reflects strength in the manufacturing sector of the economy. Automobile manufacturers had a good year in 1993, and thus their use of paint accounted for a substantial portion of the increase in shipments for the category.

Only special-purpose coatings suffered a decline in shipments. Shipments of these coatings, which include, for example, bridge maintenance and highway traffic paints, were off more than 2% in 1993 to 169 million gal, following a nearly 4% decline in 1992. The decline suggests that local, state, and federal spending on infrastructure maintenance continues to be under budgetary constraints. It also suggests that a shift to higher solids-containing coatings, which cover more area per gallon, has played a role in reducing total shipments.

In dollar terms, the value of industry shipments in 1993 rose 4% over 1992 to just under $13 billion. Revised Commerce Department data show that industry shipments in 1992 rose more than 5%, compared with 1991, to about $12.4 billion.

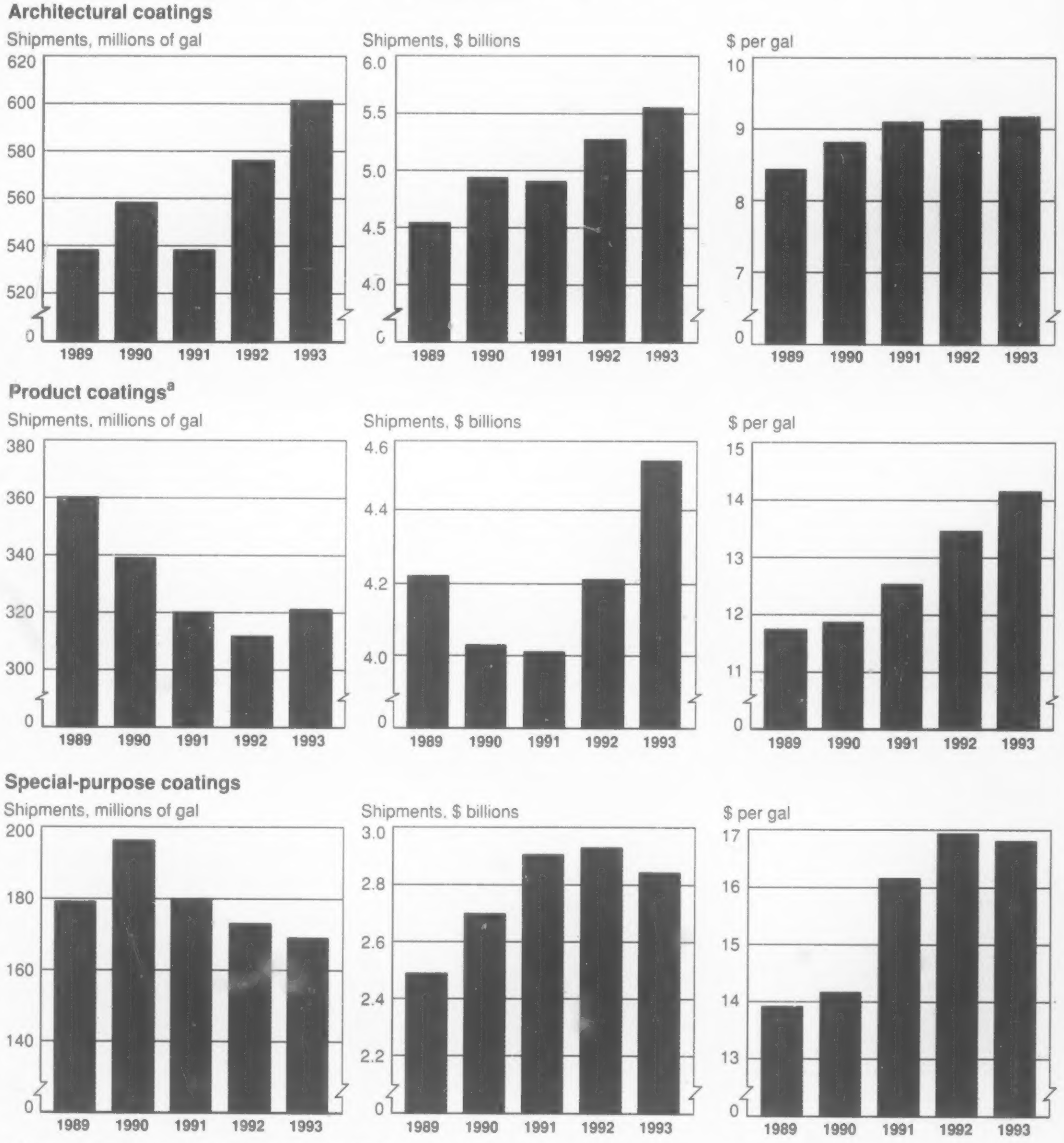
Within specific product categories, the value of architectural coatings shipments rose nearly 5% in 1993 to more than $5.5 billion, while product coatings shipments rose nearly 8% in value to more than $4.5 billion. The value of special-purpose coatings declined 3% to about $2.8 billion.

In 1993, architectural coatings accounted for 55% of all paint shipments, but only 43% of the value of total shipments. Product coatings accounted for 29% of shipments, but 35% of the value of total shipments; special-purpose coatings were 16% of all shipments, but 22% of the value of those shipments. These percentages do not change much from year to year.

A further look at paint industry data reveals that the average cost per gallon on the producer level averaged $11.82 in 1993, up less than 1% over the 1992 figure. Within individual market categories, average price per gallon for architectural paints was $9.19, up a mere penny from the year earlier. Product coatings prices rose nearly 5% to $14.14 per gal, and special-purpose coatings prices declined almost 1% to $16.80.

To illustrate the difference between producer costs, producer prices, and the cost per gallon that a retail consumer may pay, senior paint industry consultant Steven J. Nerlfi of consulting firm Kline & Co., Fairfield, N.J., notes that although architectural paint may average $9.19 on the producer level, the actual cost to produce the paint averages around $6.00 per gal. That means the paint formulator marks up the cost of paint by about 50%. The retail consumer pays, on average, $13.25

Product and architectural coatings shipments rose in 1993



a Original equipment manufacturers. **Source:** Bureau of the Census

for a gallon of architectural paint—representing a further 45% markup. The percentage markups and actual number of markups may vary by product category. For instance, paint formulators frequently sell paint directly to automobile manufacturers, who pay the producer price.

Per-gallon paint prices and material costs have been and are growing at less than the current inflation rate of between 3 and 4% for the past few years. According to the Department of Labor's producer price index, paint material costs declined almost 4% between 1990 and 1992. While average producer prices per gallon of paint rose less than 1%, paint material costs also increased less than 1% between 1992 and 1993. The period between January and August of this year shows a further increase of a little more than 1% for paint material costs. Prepared paint costs for the same period are also up about 1%.

Three main paint categories break down this way

Architectural coatings
- Exterior house paints
- Interior house paints
- Stains
- Undercoaters, primers & sealers

Product coatings[a]
- Appliances
- Automotive
- Electrical insulation
- Factory-finished wood
- Film, paper & foil
- Machinery & equipment
- Marine
- Metal containers
- Metal furniture & fixtures
- Nonautomotive transportation
- Pipe
- Sheet, strip & coil
- Toys & sporting goods
- Wood furniture & fixtures
- Miscellaneous consumer & industrial products

Special-purpose coatings
- Aerosols
- Arts & crafts
- Automotive & machinery refinishing
- Bridge maintenance
- High-performance maintenance
- Metallics
- Multicolored
- Roof
- Swimming pool
- Traffic marking

[a] Used by original equipment manufacturers. **Sources:** SRI International, Department of Commerce

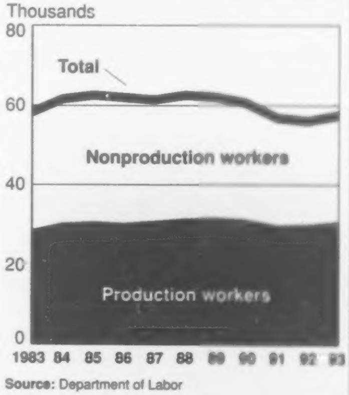
Over the next few months, prices of one of the most expensive paint ingredients, titanium dioxide (TiO_2), will probably rise. James R. Fisher, president of consulting firm International Business Management Associates, Princeton Junction, N.J., says TiO_2 prices rose 3% in April, but the increase was not fully effective until July. He expects to see another price increase—perhaps as high as 5%—by the end of 1994. Most new TiO_2 capacity is focused on serving fast-growing markets in the Pacific Rim, he notes, so prices in the U.S. and Europe for the pigment, an opacifying ingredient in most paint formulations, probably will remain high for the foreseeable future.

Over the past few years though, material price increases, including TiO_2 prices, and formulated paint price increases have been slim. Paint formulators have generally kept a cap on employment in recent years to control costs. Industry employment was 58,200 in 1993, almost 5% lower than the 61,200 level in 1990, when the industry sold just about as many gallons of paint. However, Labor Department data show that employment rose 2% in 1993 compared with 1992. To handle the increase in shipments between 1992 and 1993, the industry bolstered both production workers—to 30,500 in 1993 from 29,700 in 1992—and nonproduction workers—up to 27,700 in 1993 from 27,300 in 1992.

The slight increase in industry employment comes against a background in which the number of paints and coatings producers continues to decline. Industry sources estimate the number of coatings formulators in the U.S. at between 800 and 900. Ten years ago, around 1,300 formulators were producing in the U.S. Last year saw continuation of the trend in which large producers increase in size as they merge with or acquire others.

Perhaps the biggest business merger to affect the paint industry over the past 12 months was that of commodity and specialty chemical producers Akzo, based in the Netherlands, and Nobel Industries, based in Sweden, to form Akzo Nobel in February. In the U.S., the two companies have pooled their coatings formulations efforts in wood furniture finishes, coil coatings, and automotive refinish paints. In Europe and the Pacific Rim, the new company has strengths in those same markets; in addition, it is a major producer of decorative architectural coatings.

Paint employment is up after four years of decline



Source: Department of Labor

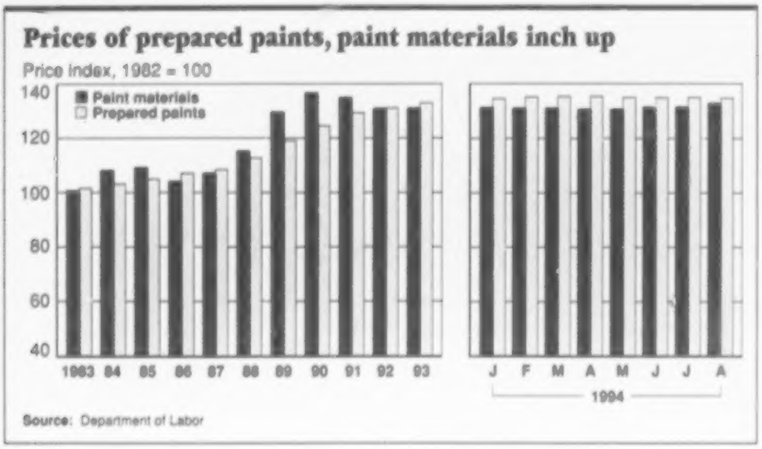
A number of smaller business mergers also took place during the past year. These include Sherwin Williams' acquisition of Old Quaker Paint, Grow Group's acquisition of Sinclair Paint, RPM's acquisition of Rust-Oleum; and Dexter's acquisition of both Potter Paint and Service Coatings. Many of these acquisitions have helped to fill in and strengthen the purchasing company's existing business. They also point out the vulnerability of smaller niche operations in a business climate where mostly the larger and better financed businesses can afford the effort to reformulate liquid coatings to lower VOCs and reduce or eliminate HAPs.

VOC reduction targets unclear

The VOC reduction targets that liquid paint manufacturers will have to meet are not yet finalized. What is clear is that paint formulators will have to lower VOC levels.

As part of its effort to help put clean air mandates into effect, the Environmental Protection Agency held a series of negotiations, which ended in August, with manufacturers of architectural and industrial maintenance coatings and interested parties. For more than two years, the group—which included manufacturers, environmental organizations, and state authority representatives—attempted to develop a plan to serve as a national framework to reduce VOCs emitted from paints. The group's goal was to come up with specific limits that would reduce VOCs emitted from paints in that category 25% by 1996, 30% by 2000, and as much as 40% by 2004—all based on 1990 emissions levels of approximately 990 million lb.

However, the group failed to reach an agreement. And the paint industry will now confront a scenario it had hoped to avoid. Bob Nelson, director of environmental affairs for the National Paint & Coatings Association in Washington, D.C., says that a number of states were counting on the national rule negotiations to use as a model in formulating their own local rules on VOCs. He says 33 states encompass localities where air



Prices of prepared paints, paint materials inch up

Source: Department of Labor

quality must be brought up to minimum acceptable standards, and thus paint manufacturers face a number of potentially differing VOC limits on liquid-coating categories.

The stakes were high in the architectural and industrial maintenance paint negotiations, Nelson points out, because the rules would have covered products that about 500 U.S. paint companies manufacture and that account for about 65% by volume of paint sold annually. If the VOC negotiations had been successful, they would have had the effect of postponing national rule making on HAP limitations for the architectural paint category until all parties could be reassembled to discuss limits. But with the failure of VOC negotiations, states can immediately begin their individual efforts to control both HAP and VOC paint rules, notes Nelson.

However, a second group, involving manufacturers of coatings for wood furniture, is now negotiating with EPA to set VOC and HAP limits simultaneously. That effort is closer to a final agreement, says Nelson, and the group is only working out the details of how limits will be monitored and how compliance will be ensured. Still other segments of the paint industry face the prospect of VOC limits in geographic regions they serve. An aerospace coatings advisory group has been discussing model VOC limits for airplane paint removal and coatings, says Nelson.

The fear among large- and medium-sized paint producers that serve a variety of geographic markets is that the Clean Air Act has opened a Pandora's box of regulations. And, as a result, they will have to deal with regulations that vary not only from state to state, but also from district to district within states where air quality restrictions could differ.

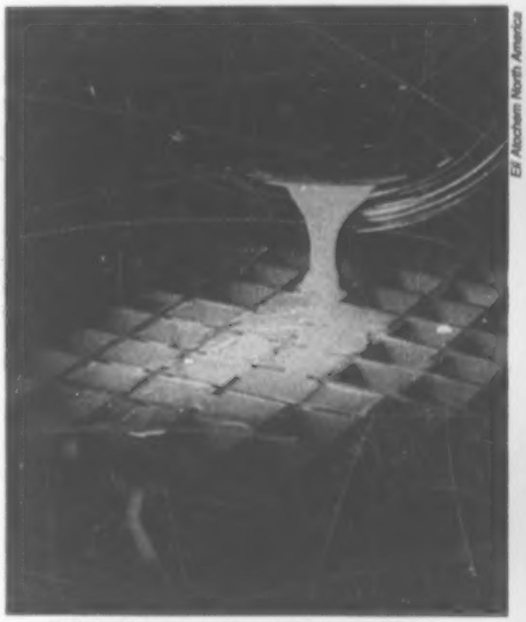
Fred Wissemann, a project manager with DuPont Auto Refinish Products, Wilmington, Del., notes he would like to see consistency among states on VOC limits affecting paint used to refinish cars in body shops. State authorities will be regulating the paints used by auto body shops as part of the effort to submit VOC reduction plans for approval to EPA. But no discussions are planned between EPA and auto refinish paint manufacturers to propose model national VOC rules. EPA is simply issuing technical guidelines to states on establishing auto refinish paint emission limits. Formulators will therefore have to make a number of individual efforts to reach state regulators if they are to secure regulatory consistency.

Akzo Nobel Coatings vice president of R&D in Troy, Mich., John L. Gardon, says the recent emphasis on pending regulation has created a climate for change in the industry. As a large supplier of coatings for industrial wood furniture finishing, Akzo Nobel sees its customers moving to high-performance aqueous coatings to replace higher solvent containing urea alkyds for kitchen cabinets. Waterborne systems to coat wood are also finally making inroads against the high-solvent containing nitrocellulose lacquer systems widely used for furniture. The automotive industry moved beyond nitrocellulose lacquer 40 years ago, notes Gardon, while the wood-coating industry stuck with older, familiar technology.

New resin developments in general have meant higher initial costs in some cases, notes Gardon. But he expects costs to moderate as new technology becomes more widespread. However, in some cases, higher costs for paints may be justified, especially when the effort to reformulate products for regulatory reasons also produces a coating system that performs better and lasts longer.

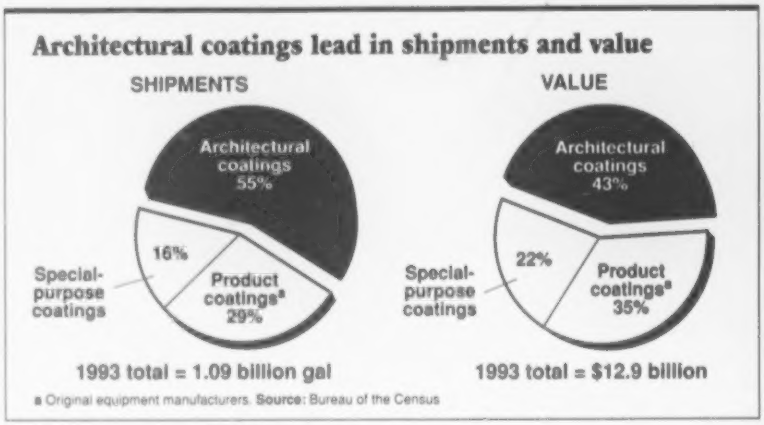
Realistically, the paint and coatings industry has been under pressure to reduce use of VOC-containing solvents for at least 15 years, notes paint industry consultant William Broxterman, president of ChemQuest Group, Cincinnati. Most large coatings formulators believe they can handle the transition to lower VOC coatings, he says. VOC and HAP concerns "are not overnight phenomena" after all, he adds. And despite the worry about regulation and its effect on business, the paint industry is relatively healthy now, he says, since

Continued on page 54



Elf Atochem North America

High-solids paint is dispensed into test trays.


Architectural coatings lead in shipments and value

1993 total = 1.09 billion gal

1993 total = $12.9 billion

a Original equipment manufacturers. **Source:** Bureau of the Census

Continued from page 50

both product sales and revenues are on the rise.

Regulations have provided opportunity for material suppliers, notes senior paint industry consultant Mike Growney, Kline & Co., Fairfield, N.J. Paint formulators will be under pressure to reduce the use of older aromatic and aliphatic solvents, among them toluene, xylene, and mineral spirits. Oxygenated solvents that are not considered HAPs should do well, he notes. In that category are solvents such as butyl acetate and ethyl acetate; propylene glycol-based products; some, but not all, ketone-based products (methyl ethyl ketone and methyl isobutyl ketone are considered HAPs); and dibasic esters.

The family of available solvents will grow, but the overall volume of solvents sold into the coatings market will decline in the long term, opines Growney. Considering the large number of specialty solvents the industry will have to choose from, prices for solvents generally will rise and will only come down if economies of scale come into play for certain preferred solvents. The search for solvent substitutes under regulatory pressure is causing a shift in both technology and thinking about the nature of coatings, he notes.

In the industrial maintenance arena, that has meant that coatings formulators and applicators are shifting to higher solids, low-solvent coatings as well as waterborne coatings. Formerly, high-solvent-content coatings were thought to perform best in industrial maintenance applications, notes consultant Jay Willner, president, WEH Corp., San Francisco. And solventborne coatings still perform best, he believes, in high-performance applications.

However, Willner estimates that manufacturers' sales of conventional lower performing, high-solvent coatings for commercial and institutional applications in schools, hospitals, and warehouses will decline from $235 million in 1993 to $185 million in 1998. Meanwhile, sales of waterborne coatings for similar applications will rise from $350 million in 1993 to $450 million in 1998. Sales of high-solids, low-solvent coatings that contain at least 60% solids will increase from $190 million in 1993 to $250 million in 1998. He believes, however, that conventional solventborne low-solids and high-solids coatings will continue to dominate industrial coatings for high-performance, severe exposure conditions, such as in petroleum plants, pulp and paper plants, and aircraft maintenance.

Solvent suppliers face VOC and HAP rules

Peter Doty, a Dow Chemical development associate, expects customers to choose solvents based on propylene glycol ether over ethylene glycol for both solventborne and waterborne formulations. Ethylene glycol solvents appear on the list of HAPs. But he points out that propylene glycols can seldom be one-for-one replacements for the ethylene glycol solvents. Reformulation with propylene glycols requires computer analysis to help find the best blend and further lab experimentation to confirm the best replacement.

On a pound-for-pound basis, however, propylene glycols contribute the same VOCs to a coating formulation as do ethylene glycols. But, says Doty, propylene glycols are "more efficient," and often a paint formulation requires less propylene glycol than ethylene glycol, thereby resulting in a lower VOC formulation. The cost to substitute propylene glycol for ethylene glycol depends on the ratio of substitution, but propylene glycol-containing formulations will generally be "slightly to moderately" more expensive.

Separately, Dow has introduced a new product, Proglyde DMM, a propylene-based di-ether, for use in both waterborne and solventborne urethanes. Its principal advantage is that it does not react with isocyanate-containing urethanes, and it provides good flow and leveling characteristics to the urethane coatings.

Dow Chemical technician evaluates panels for compliance with VOC regulations.

Arco Chemical, Newtown Square, Pa., is also a producer of propylene glycols. The company's product development manager, Zee Pongonis, says the company is also focusing its efforts on substituting propylene glycol-based products for ethylene glycol-based coalescents in waterborne coatings. In addition, the company has a line of reactive intermediates, such as 2-methyl-1,3-propanediol, to help lower the use of VOCs in urethane and polyester coatings. When the intermediate is "cooked into the backbone" of a monomer system, it produces a high-solids coating offering improved durability, weatherability, and gloss retention in industrial maintenance coatings, notes Pongonis.

International Specialty Products in Wayne, N.J., is hoping its *n*-methyl-2-pyrrolidone (NMP) will replace HAP solvents in both waterborne and high-solids solvent coating systems. According to global marketing director Van Rhonheimer, depending on the testing method, NMP "in general makes no VOC contribution." It is, however, a good coalescing agent in waterborne formulations, and it can replace more conventional solvents in solventborne coatings. NMP is not, however, a simple drop-in replacement for other solvents; it requires formulations study before being used in a coating.

Occidental Chemical, Dallas, has introduced a 35-year-old agricultural intermediate as a coating solvent because it is not a HAP, and it could qualify as a no-VOC contributor. Occidental Chemical has petitioned EPA to accept *p*-chlorobenzotrifluoride, trade named Oxsol 100, as a non-VOC, according to marketing manager Diane M. Tramontana. The company is currently testing the performance of Oxsol 100 in alkyd resins for architectural and industrial maintenance use versus currently used solvents. Because of Oxsol 100's price, Tramontana expects to see some blending of Oxsol 100 with more conventional VOC solvents as customers try to balance the final price of using the product against their ultimate VOC target.

Eastman Chemicals' Ron Litton, principal technical representative and supervisor of the company's coatings laboratory in Kingsport, Tenn., says Eastman's oxygenated solvents are aiding the ongoing effort to formulate away from HAP solvents. The company offers propylene glycol ethers, and its Texanol ester alcohol is a non-HAP coalescent that Litton says has been a standard in waterborne architectural coatings for more than 25 years. High molecular weight ethylene oxide glycol ether solvents supplied by Eastman to coatings formulators are still considered HAPs according to the Clean Air Act, but Litton says he hopes that EPA will change the designation.

A reactive diluent in a coating can also replace some solvent that would otherwise be required in a solventborne formulation, says Bill Reutz, technical oils department manager for Cargill, Minneapolis. The company's Dilulin diluent is a patented low-viscosity linseed oil copolymer with dicyclopentadiene. Dilulin is "basically a zero VOC" product, says Reutz, but since it increases the solids content of an oil-based coating, it goes on a surface as a thick coat that takes a longer time to cure than do conventional solventborne coatings.

Latest version of proposed national rules to limit VOCs in architectural and maintenance coatings

After two years of discussions, the industry group that EPA assembled to negotiate volatile organic compound (VOC) limits failed to agree on a final rule by the end of August. However, most group members could agree on the following VOC limits with help from EPA moderator Keystone Center, Keystone, Colo. Many within the paint industry hope the negotiated limits will provide a basic set of VOC limits for state authorities as they develop a variety of regulations to improve regional air quality to meet clean air mandates.

Category[a]	Proposed VOC limit (lb per gal)		
	1996	2000	2004
Flat coatings			
Exterior			
Solventborne	2.08	1.66	1.25
Waterborne	2.08	1.66	1.25
Interior	1.66	1.25	0.83
High-performance coatings			
Floor	3.33	2.92	2.5
Rust preventative	3.33	2.92	2.5
Concrete protective	3.33	2.92	2.5
Industrial maintenance coatings	2.92	2.92	2.5
Lacquers	5.66	5.42	5.0
Metallic pigmented coatings	4.16	3.75	3.33
Primers & undercoaters			
Waterborne	1.25	1.25	1.25
Solventborne	2.92	2.08	2.08
Quick-dry coatings			
Enamels	3.75	2.92	2.5
Primers, sealers & undercoaters	3.75	2.92	2.5
Roof coatings	2.08	1.66	1.66
Sealers—including specialty sealers	3.33	2.92	2.92
Shellacs			
Clear	5.42	5.0	5.0
Opaque	4.58	4.16	4.16
Stains			
Opaque			
Solventborne	2.08	2.08	1.66
Waterborne	1.66	1.66	1.25
Semitransparent	4.58	3.33	2.92
Low solids	1.0	1.0	1.0
Traffic-marking paints	1.25	1.25	0.83
Varnishes	3.75	2.92	2.5
Waterproofing sealers			
Clear	5.0	3.75	3.33
Opaque	3.33	3.33	3.33

[a] Proposed rule contains more than 50 paint categories. This table shows a representative sampling. **Source:** Keystone Center

Resins are one key to lower VOC

Kline & Co.'s Nerlfi believes that the development of new resin technology will make all the difference in the formulation of low-VOC coatings. Winning resin technologies, he says, include acrylic, polyester, epoxy, and aliphatic urethane formulations—all of which can be formulated as high-solids, low-VOC coatings or waterborne coatings. Losing technologies, he suggests, will be those that require a large amount of solvents (up to 70% by volume) for application, including nitrile, chlorinated rubber, neoprene, polyvinyl chloride, and alkyd formulations.

David Watson, maintenance coatings market manager for Rohm and Haas, Philadelphia, says waterborne acrylics can and do perform well in the tough, high-performance industrial maintenance arena.

Despite user preference for solventborne coatings, Rohm and Haas has made inroads in the industrial maintenance market. For instance, the company recently introduced Maincote PR71, a waterborne acrylic resin for priming metal. Watson says the resin can be used in a formulation with VOC levels well under 2 lb per gal, an improvement over high-VOC vinyl wash primers frequently used, and an emission level that could meet tentative EPA criteria for high-performance rust-preventive coatings.

In addition to its well-known acrylic resins for waterborne coatings, Rohm and Haas offers acrylic polyols to formulate urethane coatings. The company now also has some waterborne acrylic polyols designed for use with wood coatings. And it is trying to develop waterborne acrylic polyols for the industrial maintenance business as well, says Watson. "We find waterborne coatings perform well in general, but it is hard to convince people [of that]," says Watson.

Another new technology for waterborne coatings is the development of a reactive coalescent that allows the formulation of coatings that contain essentially zero VOCs, says Watson. The coalescent is a monomer known as dicyclopentenyloxyethyl methacrylate, which Rohm and Haas conveniently refers to as QM57. The monomer self-cross-links in the finished coating. It is more expensive than traditional coalescents, notes Watson.

Pittsburgh's 9th Street Bridge was recently repainted with a three-coat polyurethane system containing coating resins made by Miles Inc.

Another manufacturer of urethane polyols, Miles Inc., based in Pittsburgh, has also put considerable effort into the development of waterborne systems as well as of high-solids, low-solvent systems. The company has helped the Navy develop a two-part waterborne polyurethane coating now being tested on the P-3 aircraft. The trick, says John L. Williams, Miles vice president of industrial finishes and resins systems, was to get the isocyanate cross-linker in the coating to disperse in water yet not react too quickly in water. The new gray coating has a

VOC level of 1.76 lb per gal versus 3.5 lb per gal for the solventborne version.

Miles continues to develop both polyester and acrylic polyols for high-solids and waterborne system formulators, says Williams. In solvent systems, urethane formulators are making an effort to stay away from HAPs. However, Miles finds that when formulators move to low- or no-VOC systems, they also are able to remove HAP solvents from their systems. The efforts to reduce or eliminate HAPs and VOCs go hand in hand.

Air Products, Allentown, Pa., also produces urethane polyols. Larry E. Iceman, director of the company's industrial coatings initiative, says the company has recently introduced a line of patented hybrid acrylic urethane dispersions for water-reducible coatings. Sold under the Flexthane trade name, the new dispersions make it possible for formulators to produce polyurethanes with VOC levels of about 1.5 lb per gal. Iceman says the dispersions will be used in light- to medium-duty industrial maintenance and wood coatings. This fall, Air Products plans to introduce a two-part thermoset system for formulators based on Flexthane technology.

Air Products has also developed a modified aliphatic amine supplied in water and intended for use with other resin manufacturers' waterborne epoxy dispersions. The epoxy curing agent, Anquamine 401, cures rapidly and develops high gloss and good chemical resistance and is intended for use in systems to coat steel or concrete substrates, says Iceman.

Ultimately, says Iceman, Air Products' goal is to develop zero-VOC technology to end the "spiral" of lower and lower VOC-containing products. It is "expensive for everyone to constantly reformulate," he says.

Dow Chemical's Mark Sullivan, coatings market manager based in Midland, Mich., says Dow is offering customers a new epoxy powder that can be dispersed in water and formulated to contain no VOCs. Referred to by the rather unwieldy designation XUS 19,000.01, the epoxy powder can be a component in a two-part epoxy coating for industrial maintenance and institutional use such as in hospitals.

If customers prefer to work with solvent epoxies, Sullivan says Dow's new bisphenol F epoxy resins offer low viscosity and a high level of chemical resistance for civil engineering structures. The cost of the resin is twice that of bisphenol A epoxy, but the bisphenol F material allows the formulation of a high-solids resin. In prior years, performance drove development of new resin systems, Sullivan points out. Today, the effort to meet regulatory limits is of equal importance to performance-driven improvements, he says.

Eastman Chemical recently started up a new plant in Kingsport to produce commercial quantities of an intermediate in the production of polyester resins. Dennis J. Golob, market development manager in Eastman's coatings, inks, and resins business organization, says that 1,4-cyclohexanedicarboxylic acid is a monomer that poly-

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Paints use many hazardous air pollutants

Next month, a New York City-based environmental group, Inform, plans to publish a book, "Stirring Up Innovation," profiling five paint material suppliers and formulators that have successfully produced more environmentally benign products. The book's principal author, John S. Young, Hampshire Research Institute, Alexandria, Va., says the book will "highlight positive steps which can be taken in pollution prevention."

The book features paint material suppliers Ciba, Hüls America, and Miles Inc. for advances in marine antifoulants, colorants with no volatile organic compounds (VOCs), and polyurethane bridge coatings, respectively. It profiles Devoe & Raynolds and Glidden for low- or no-VOC paint developments.

In a discussion of environmental issues confronting paint formulators, "Stirring Up Innovation" inventories the following compounds used in paints that are identified as hazardous air pollutants in the Clean Air Act of 1990.

Acetamide
Acrylamide
Acrylic acid
Acrylonitrile
Allyl chloride
Aniline
Benzene
1,3-Butadiene
Caprolactam
Catechol
Cumene
1,2-Dichloroethane
Dichloroethyl ether
Diethanolamine
Dimethylamino-azobenzene
Dimethylformamide
Dimethyl phthalate
Epichlorohydrin
Ethyl acrylate
Ethylbenzene
Ethylene dibromide
Ethylenimine
Formaldehyde
Hexachlorobenzene
***n*-Hexane**
Hydroquinone
Isophorone
Maleic anhydride
Methanol
Methyl ethyl ketone
Methyl isobutyl ketone
Methylene chloride
Naphthalene
Nitrobenzene
2-Nitropropane
Pentachlorophenol
Phenol
Propylene oxide
Styrene
1,1,2,2-Tetrachloroethane
Toluene
2,4-Toluene diisocyanate
1,1,1-Trichloroethane
Trichloroethylene
2,4,6-Trichlorophenol
Vinyl acetate
Vinyl chloride
Xylenes
***m*-Xylene**
***o*-Xylene**
***p*-Xylene**

ester resin producers can incorporate into the backbone of a polyester resin.

The monomer modifies the polyester's performance, says Golob, making it tough, flexible, and chip resistant. It was first used in high-solids solventborne resin systems. But because the monomer gives polyester resins a new level of hydrolytic stability, it improves polyester resin performance in waterborne systems now under development.

Nacan, the Canadian affiliate of National Starch, Unilever's U.S. chemicals operation, has developed a line of acrylated ethylene vinyl acetate terpolymer emulsions that can be formulated into a flat or semigloss paint containing no solvents used as coalescents. The paint thus can be VOC free. According to Bill Currie, technology manager based in Nacan's Brampton, Ontario, headquarters near Toronto, the terpolymer, trade named Vinamul 3692, is manufactured in Woodruff, S.C., on the basis of technology Nacan brought to the U.S. from its Scandinavian and German affiliates.

Paint formulations based on Vinamul 3692 are now in use for architectural coatings, says Currie, and soon could find their way into industrial maintenance coatings. In addition, Nacan manufactures two all-acrylic emulsions for architectural coatings, Nacrylic 2592 for semigloss paints and Nacrylic 2792 for lower luster eggshell paints. Formulators also can use both emulsions to produce solvent-free coatings, says Currie. The acrylic emulsions are manufactured in Canada.

Even resin systems some may consider hopelessly tied to solvents have potential for development in an era of low-VOC paints. According to Vince S. Misiti, business development manager for ICI Industrial Surfactants in Wilmington, Del., the company offers a surfactant to emulsify alkyds in water, Atlas G-3969, and another surfactant, IL-2580, to emulsify epoxies in water. Misiti says these surfactants may be added at 5 to 10% by weight to the resins. The surfactants sell at a premium. Cost, says Misiti, is not so much the issue as are the environmental benefits that water-reducible resins provide. These surfactants will contribute some VOCs, but their contribution in a paint system will be much lower than that from a conventional solvent, he says.

Some manufacturers have attempted to produce lower molecular weight polymer versions of their high molecular weight solventborne polymers, says Misiti. The lower molecular weight materials dissolve more readily in water. But Misiti believes they would be better off with the higher molecular weight polymers to maintain the coating systems' strength and durability and instead utilize any number of ICI surfactants.

Surfactants may also replace some coalescing solvents in waterborne systems, says Misiti. ICI offers an ultralow-VOC specialty surfactant, Pycal 94, which can replace up to half of high-VOC coalescents such as ester alcohols and thus produce a latex paint with a VOC level as low as 0.5 lb per gal.

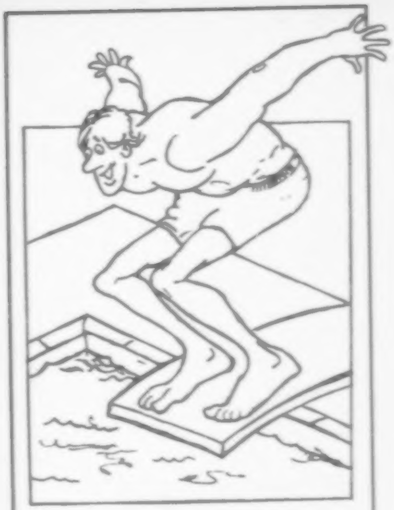
3M, Minneapolis, has a line of fluorochemical surfactants to lower the surface tension of waterborne coatings, especially when coalescing solvents have been removed from the formulation, comments chemical specialties marketing manager James W. Simmons. Although fluorochemical costs are relatively high compared with other surfactants, the fluorochemical surfactants are added at low enough levels to be competitive, he says.

Low molecular weight polymer additives can impart better performance characteristics to high solids and waterborne coatings. AlliedSignal's low molecular weight polyethylene resin modifiers, sold under the ACtol trade name, can improve the flexibility and impact resistance of reformulated coatings, says Arthur DeMonte, Western Hemisphere coatings marketing manager.

DeMonte says that AlliedSignal is also working with manufacturers on systems to improve highway striping paints. Where traditional highway paints are solventborne, new alternative thermoplastic tapes may be heated and applied to the road without emitting VOCs as the tapes cool and harden. AlliedSignal's new Polyace 573, a maleic anhydride-grafted polyethylene, can be used as an adhesion promoter for this technology, says DeMonte.

Elf Atochem North America, Philadelphia, has introduced new organic

Continued on page 64



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Testing is vital to ensure performance of reformulated paints

A. D. Little technician characterizes barrier properties of weathered paint panel.

Paint formulators are generally reluctant to reformulate a paint that has a history of good performance. "Why fool with success?" they may ask. But the existing and pending limits on volatile organic compounds (VOCs) and hazardous air pollutants (HAPs) are forcing paint makers to reformulate many of their liquid-coating lines. Testing the new paints is more important than ever.

According to John Martin, senior consultant in the polymer applications group for consulting firm Arthur D. Little, Cambridge, Mass., paint industry clients have generated a great deal of R&D activity on the issue of VOC reductions. "We can help the small- to medium-sized companies do the testing on reformulated coatings that the large companies with high R&D budgets can afford," he says.

About 5% of the 225 staff scientists at A. D. Little's Center for Product Development in Cambridge focus on corrosion and coatings, says Martin. The company undertakes research projects that range in duration from one month to several years.

Many paint companies use subjective methods to evaluate the performance of coatings, says Martin. But the use of lab analysis—objective methods—of coatings can yield good predictions on long-term performance of reformulated coatings. A new electrochemical technique that A. D. Little scientists use with painted panels entails outdoor exposure for 30 days and correlates to two years of exterior exposure. The technique allows paint formulators or material suppliers to tell in a month how new products may perform over the long term.

peroxides for use in acrylic resin production that allow the formulation of high-solids solventborne coatings. James D. Sargent, market manager for coatings, styrenated and specialty polymers, says *tert*-amyl peroxide initiators help resin makers produce an acrylic with a narrow molecular weight distribution that allows the production of a high-solids (up to 75%), low-viscosity resin for spray applications. The new peroxides are slightly more expensive than the *tert*-butyl peroxide or azonitrile initiators they are meant to replace, says Sargent.

To aid the development of low- or no-VOC paints, Hüls America, Piscataway, N.J., has a line of zero-VOC colorants. Thomas E. Maggio, executive vice president for colorants and coatings additives, says the Covon (no-VOC spelled backwards) line of colorants provides good drop-in replacements for VOC-containing glycol-based colorants more widely used now. Higher costs for some Covon system raw material ingredients have made the colorants more expensive than standard colorants, but Maggio expects prices to moderate as volumes increase.

Engelhard, based in Edison, N.J., also has a line of colorants that are solvent free or very low in VOCs for in-store custom coloring of consumer paints. The Gallery One Solvent Free line of colorants contains either no VOCs or such low levels of VOCs that VOC amounts are barely detectable, says Eliot Burrows, universal colorants business manager.

Colorant development group leader Jeff Norris says Engelhard is trying to anticipate government regulations by acting even if an ingredient only appears to be suspect. When concern was raised over the biodegradability of alkylphenol surfactants in colorants, Engelhard removed them from its line of colorants for manufacturers' use in their paint plants and introduced a new line of solvent-free colorants called Aurosperse II.

Heraeus DSET Laboratories in Phoenix can also assist clients in evaluating performance of reformulated coatings against traditional formulations that have years of testing behind them. William J. Putman, test services manager, says the company has two weather-testing sites: one in southern Florida, where paint panels are exposed under bright, hot, and humid conditions; and another in Arizona, where test panels may be exposed to high ultraviolet light at a hot, dry site.

The trick in evaluating new paints is in choosing the appropriate method to compare paints exposed under extreme accelerated test conditions with real-time exposures. Putman says that Heraeus, a privately held concern, works with customers to choose the most appropriate accelerated testing methods.

Air Quality Sciences (AQS), Atlanta, Ga., can verify for clients whether they have indeed succeeded in reformulating their coatings to reduce emissions. Many school districts and federal contracts put specific limits on the amount of VOCs that paints may emit during redecoration, says Marilyn S. Black, chairman of the testing company. AQS can provide independent verification that paints will perform as required, she says.

AQS can also perform a standard test to measure VOCs emitted from paint as it dries. The company uses a small stainless steel test chamber to measure VOCs emitted from paint by gas chromatography-mass spectrometry. Paints may also be evaluated in a room-sized environmental test chamber. Wallboard placed in the chamber and then painted allows AQS to provide its clients with a chemical analysis of chamber air, thereby giving a summary of chemicals to which a room's occupant may be exposed as paint dries. Black says that a basic test and chemical emissions report, which highlights chemical emissions that raise regulatory concerns, costs $1,600 per paint sample.

Heraeus DSET Labs

Paint exposure testing is conducted with a sun-tracking carousel.

Pending and future government regulations also affect the producers of specialty silicone materials—fluids and resins—that are added to paints and coatings. Fluids are added in minute amounts to impart antifoam and good wetting characteristics to paints. Resins are added to alkyd or polyester resins to formulate heat-resistant, gloss-retentive coatings with good weathering characteristics. And silicone products and silanes also may be used to waterproof concrete and masonry materials.

The size of the market for these silicone additives is difficult to gauge. Industry sources estimate that annual U.S. consumption of silicone fluids is about 170 million lb, of which paint and coating additives are a very small part. The fluids are typically added to paints at less than 1% by volume. U.S. silicone resin consumption is probably about 12 million lb per year, of which perhaps 4 million lb are used in paint resins. Sources say high costs limit silicones to specialty applications.

But performance is not the only criterion by which silicones are measured anymore. Silicone suppliers are also working to make products that contain low or no VOCs and no HAPs. Despite the small volumes of silicones used in paint, the U.S. paint market attracts a good number of competing suppliers—including Dow Corning, Wacker, General Electric, Miles, Hüls America, Rhône-Poulenc, and OSi Specialties.

Perhaps the largest supplier to the paints and coatings industry is Dow Corning, Midland, Mich. According to Steve E. Tracy, senior product marketing specialist, silicone additives offer mar resistance, promote adhesion and water resistance, help with leveling and wetting paint off the brush, and prevent foaming of paint. The continuing move to waterborne coatings, he notes, has enlarged the market for silicone additives to provide some of the attributes of a coating lost in reformulating from solventborne technologies.

While he did not quote prices, Tracy

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USP

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does say that the additives offer a large benefit relative to their cost because they are often added at levels of 0.1% by volume to a paint formula. To measure the impact on paint formulation costs, a paint maker needs only to divide the additives' cost by 0.1% to see its impact.

Although paint additives are included in coatings in minuscule amounts, Dow Corning is formulating its additives to remove VOCs where possible, says coatings additives and resins industry manager Kim Evans. The same is true of Dow Corning's resins for paints. Many of the items in Dow Corning's product line are dissolved in HAP solvents, so the company is making an effort to upgrade its entire line.

One way in which Dow Corning intends to upgrade is through the production of dry-flake resins, such as the company's 10543 resin, which a paint formulator may emulsify in water. Another upgrade is the introduction of new emulsions for high-temperature applications including auto muffler and under-the-hood paints, such as resins 10468 and 10469, says Evans.

But while some formulators are making the leap to waterborne technology for certain products, others are taking a more cautious route with some high-performance coatings. In these cases, coatings manufacturers are first reformulating from low-solids to high-solids coatings before introducing a waterborne version, says Evans. To aid the development of high-solids, lower VOC, air-dried coatings for smokestacks, Dow Corning has introduced silicone resin 10418.

Technician at A. D. Little Coatings Laboratory prepares drawdowns for reformulation study of new coatings.

Dow Corning technician tests viscosity of paint containing a silicone additive.

Evans says that Dow Corning also provides silicone materials for the formulation of masonry waterproofers. The company markets silanes used in clear, penetrating waterproofing coatings for parking decks as well as silicone latex emulsions used in pigmented waterproofing coatings for structural facades.

The production of low-VOC silicones is also a goal of Wacker Silicones, Adrian, Mich., the U.S. subsidiary of Wacker Chemie, Munich. In general, silicones are expensive, confesses Gudrun Windfuhr, construction and coatings industry market manager, but "you pay for the performance."

Wacker provides a variety of silicones that are applied to masonry surfaces to protect them from water damage. Siliconates and silicone emulsions are most often applied to masonry in water-based solutions. However, the company has introduced a microemulsion silicone concentrate that is low in viscosity and solvent free. The company says that aqueous solutions can be formed by simply pouring the microemulsion into water. However, the solution must be used within 24 hours after mixing with water if it is to effectively penetrate masonry. Wacker produces the microemulsion and other silicones—such as silanes, siloxanes, and siliconates—in Germany as well as in the U.S.

Roy Anderson, general manager of silanes and silicones for Hüls America, says the company is developing formulas for waterborne silicones because of existing and pending VOC regulations. Hüls has developed a series of organofunctional waterborne silanes, sold under the Hydrosil trade name, to promote adhesion in latex paints. The waterborne silanes required development of new technology because silanes are typically unstable in aqueous solutions, says Anderson. They may be incorporated into a latex formula at 2% or less by weight.

Hüls' line of masonry treatments has been expanded with a neat silane dispersed in water and sold under the Aquatrete trade name. Use of these masonry water repellents is growing, says Anderson, but is tied to construction activity. Typical uses include application to concrete decks in garages and bridges to repel water and help prevent corrosion of the steel rebar enforcement embedded in the concrete.

Miles has only recently entered the U.S. market with a line of silicone additives made by its German parent, Bayer. According to Miles' silicones product manager, Ken Kutzer, the company produces a line of polydimethyl siloxanes and phenyl methyl siloxanes to allow for better flow and defoaming of paints. At $10 to $12 per lb, the additives are not expensive—especially when they are added to a paint formulation at between 0.1 and 0.3% by weight, says Kutzer. Miles plans to introduce a line of four additives for water-based paints this fall, he says.

GE Silicones, Waterford, N.Y., is "looking into" the development of high-solids and water-reducible high-temperature resins, says Curtis Hughes, paints and coatings industry manager. When those products are developed, Hughes says, GE "plans to be a formidable player."

The use of silicone, like that of so many other paint ingredients, is now undergoing a reevaluation in light of regulatory pressures. Ultimately, successful material suppliers and formulators will produce products that comply with the most stringent regulations and offer the performance consumers are willing to pay for. ☐

ACS Committee On Professional Training 1993 Annual Report

The number of bachelor's degree graduates in chemistry from colleges and universities whose undergraduate chemistry programs are approved by the American Chemical Society increased 4.3% in the 1992–93 academic year. The number of master's degrees from these departments increased by 4.1%, but the number of Ph.D. degrees granted decreased once again, showing a drop of nearly 3%.

The percentage of baccalaureate graduates certified to ACS was 41%. This number has remained fairly constant over the years. (Certified graduates are those who have completed a curriculum that meets the guidelines specified by ACS and who are eligible for full membership in ACS; noncertified graduates may become associate members of ACS upon graduation and full members after three years of professional experience or a higher degree in a chemical science.)

Total numbers of bachelor's degrees (certified and noncertified), master's degrees, and Ph.D. degrees awarded in 1992–93 by departments whose undergraduate chemistry programs are ACS approved are listed by institution in the large table at the end of this report and are summarized in the two smaller tables. These tables also include numbers of chemical engineering graduates from institutions whose programs are accredited by the American Institute of Chemical Engineers (AIChE) and the Accreditation Board for Engineering & Technology (ABET). [Note: These departments are not required to report their data to the Committee on Professional Training (CPT), so the number of departments included varies each year.] Also accompanying this report is a table with information on graduate student enrollments in chemistry departments whose undergraduate programs are approved by ACS.

The number of bachelor's degrees in chemical engineering from the 104 AIChE-ABET-accredited departments that reported in 1993 increased by 3.4%, even though fewer schools reported their data to ACS than in 1992. At the graduate level, the number of chemical engineering master's degrees decreased by 8.3%, and Ph.D. degrees dropped by 19.3%. However, for both categories, the number of schools reporting data to ACS was down from 1992.

The chemistry programs at ACS-approved schools normally are reevaluated at five-year intervals. There were 604 colleges and universities on the approved list at the end of 1993. During the year, the committee studied the reports of 197 chemistry programs at approved schools and 14 reports from schools applying for ACS approval. Each evaluation involved a review of extensive documentation submitted by the department chairman describing the current status of the program.

Three schools were added to the ACS-approved list by CPT; five were placed on probation; three were removed from probation; and two were removed from the approved list. Visiting

Summary of data from departments offering an ACS-approved program, 1989-93

	Bachelors				Masters		Doctorates	
	Number of schools	Graduates (totals)	Certified graduates[a]	Noncertified graduates	Number of schools	Graduates	Number of schools	Graduates
CHEMISTRY								
1993	603	8,800	3,605	5,195	313	1,683	191	2,140
1992	601	8,435	3,604	4,831	314	1,617	192	2,202
1991	599	7,872	3,310	4,562	316	1,600	189	2,213
1990	599	7,650	3,213	4,437	317	1,605	187	2,131
1989	593	8,125	3,384	4,741	318	1,710	189	1,970
CHEMICAL ENGINEERING[b]								
1993	104	3,164	3,164	—	96	705	84	435
1992	112	3,060	3,060	—	107	769	92	539
1991	121	3,087	3,087	—	116	821	104	602
1990	126	3,170	3,170	—	122	956	106	583
1989	115	2,891	2,891	—	113	919	95	574

a Includes graduates certified in approved options. b Chemical engineering departments are not required to report their data to CPT, so the number of departments included in this category varies from year to year.

Summary of totals from 1993 reports from departments offering an ACS-approved program

	Schools reporting	Men	Women	Total
CHEMISTRY				
Bachelors, Total	603[a]	5,228	3,572	8,800
Certified	—	2,225	1,380	3,605
Noncertified	—	3,003	2,192	5,195
Masters	313	1,003	680	1,683
Doctorates	191	1,523	617	2,140
CHEMICAL ENGINEERING				
Bachelors,				
Certified	104[b]	2,112	1,052	3,164
Masters	96	564	141	705
Doctorates	84	377	58	435

a One school did not report data. There were 604 ACS-approved programs in the 1992–93 reporting year. b Report forms were sent to 146 schools; only 104 departments responded.

associates of the committee made on-site visits to five schools.

Currently, students may receive certified degrees in chemistry with options in biochemistry, chemical physics, chemistry education, environmental chemistry, materials, or polymers. By the end of 1993, the committee had approved 62 programs with a biochemistry option; one with a chemical physics option; four in chemistry education; and nine with a polymers option. No applications for approval of materials options were reviewed in 1993, and the environmental chemistry option was not adopted until 1994.

In 1993, the committee continued discussion of the requirements for an ACS-approved option in environmental chemistry. Comments from the academic community were carefully considered by the committee members, and some modifications were made to the original proposal. Generally, the responses were enthusiastic, but a few respondents expressed concern that the options are too inflexible for undergraduates and that they pull students away from the traditional chemistry major. The committee welcomes further discussion of these concerns and invites those interested to comment by letter or directly with the members of CPT at an open meeting. The committee adopted the environmental chemistry option at its January 1994 meeting. The statement of requirements and application forms are available from the Office of Professional Training, ACS, 1155—16th St., N.W., Washington, D.C. 20036.

In October 1993, CPT published the 20th edition of the "ACS Directory of Graduate Research" (DGR). For the first time, programs in food science, forensic science, marine science, and toxicology were included in the directory. Complimentary copies were distributed to all departments listed in the 1993 directory and to all ACS-approved programs.

Also, in cooperation with the ACS Office of International Activities, the committee adopted a policy for distribution of complimentary copies of past editions of the DGR to chemists in appropriate foreign nations. The committee prepared a final report on the results of a survey of enrollment trends in freshman and sophomore chemistry courses and the numbers of chemistry majors at ACS-approved programs, and the chairman of CPT presented the results as part of a symposium sponsored by the ACS Division of Chemical Education. In institutions of all sizes, the survey data showed that more than half of the institutions responding experienced sizable increases in fall chemistry enrollments during the survey period (1988–92).

Other activities of the committee included discussion of how CPT might support the National Science Foundation's initiative in undergraduate chemistry curriculum development, revision of the five-year report form used to reevaluate ACS-approved programs, development of plans to meet with chemical industry representatives to discuss the skills that industrial employers are seeking in chemistry graduates, and endorsement of the ACS task force initiative to encourage study abroad experience for chemistry students. In addition to the enrollment survey presentation, members of the committee also participated in other symposia held at ACS national meetings by giving presentations on the evolution of the CPT perspective on instruction in chemical information and on defining performance goals for the introductory chemistry course.

The committee would like to acknowledge and thank the following visiting associates of the committee who conducted on-site visits to schools on the approved list or applying for ACS approval during 1993: Charles A. Arrington Jr., Furman University, Greenville, S.C.; Ronald L. Christensen, Bowdoin College, Brunswick, Me.; James E. Finholt, Carleton College, Northfield, Minn.; Frank A. Guthrie, Rose-Hulman Institute of Technology, Terre Haute, Ind.; and Robert J. Hargrove, Mercer University, Macon, Ga. ☐

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Walter S. Trahanovsky
Iowa State University, Ames
C. David Gutsche, *consultant*
Texas Christian University,
Fort Worth
Karen W. Morse, *consultant*
Western Washington University,
Bellingham
Cathy A. Nelson, *committee secretary*
Stacie D. Marshall, *staff associate*
Dolphine S. Hite, *program assistant*
American Chemical Society

Graduate student enrollments in departments whose undergraduate chemistry programs are ACS approved

	Number of departments	First-year graduate students		All graduate students	
		Full time	Part time	Full time	Part time
M.S. DEPARTMENTS[a]					
Fall 1992	124	524	246	1,447	858
Fall 1991	124	511	262	1,424	909
Fall 1990	125	511	268	1,244	887
Fall 1989	130	429	238	1,013	834
Fall 1988	127	420	218	998	855
Ph.D. DEPARTMENTS					
Fall 1992	189	3,649	170	15,926	995
Fall 1991	192	3,736	267	16,864	1,170
Fall 1990	189	3,535	256	15,470	1,148
Fall 1989	187	3,464	159	15,222	1,207
Fall 1988	189	3,320	171	15,125	1,111

[a] Departments whose highest offering is the master's degree in chemistry

Chemistry and chemical engineering degrees awarded by schools offering an ACS-approved program, 1992-93

	CHEMISTRY				CHEMICAL ENGINEERING		
	Bachelor's certified						
	Yes	No	M.S.	Ph.D.	B.S.	M.S.	Ph.D.
Abilene Christian U	4	1	0	—			
Adelphi U	0	1	6	—			
Agnes Scott C	1	1	—	—			
Akron, U of	19	0	2	12	(a)		
Alabama, U of							
Birmingham	3	8	1	2			
Huntsville	3	4	2	—	(a)		
Tuscaloosa	3	8	2	11	18	1	1
Alaska, Fairbanks, U of	2	2	2	0			
Albion C	0	10	—	—			
Albright C	6	6	—	—			
Alfred U	1	1	—	—			
Allegheny C	0	15	—	—			
Alma C	7	4	—	—			
American U	3	0	9	10			
Amherst C	0	5	—	—			
Andrews U	2	0	—	—			
Appalachian State U	4	5	0	—			
Arizona State U	17	13	8	13	12	6	6
Arizona, U of	12	9	8	21	(a)		
Arkansas State U	3	5	4	—			
Arkansas Tech U	1	3	—	—			
Arkansas, U of							
Fayetteville	4	4	4	12	35	8	1
Little Rock	4	8	1	—			
Ashland U	0	2	—	—			
Auburn U	15	3	11	4	62	14	5
Augsburg C	9	0	—	—			
Augustana C							
Illinois	1	8	—	—			
South Dakota	3	4	—	—			
Austin C	0	7	—	—			
Austin Peay State U	2	6	—	—			
Baldwin-Wallace C	2	17	—	—			
Ball State U	15	7	8	—			
Barnard C	0	6	—	—			
Bates C	3	5	—	—			
Baylor U	5	11	1	3			
Beloit C	0	12	—	—			
Bemidji State U	12	14	—	—			
Birmingham-Southern C	0	3	—	—			
Bloomsburg U	5	4	—	—			
Boise State U	0	5	—	—			
Boston C	5	5	3	6			
Boston U	19	4	5	13			
Bowdoin C	0	25	—	—			
Bowling Green State U	12	11	8	0			
Bradley U	0	12	0	—			
Brandeis U	0	9	5	7			
Bridgewater State C	3	5	3	—			
Brigham Young U	11	22	1	8	27	4	1
Brown U	0	22	1	12	4	2	0
Bryn Mawr C	12	0	5	0			
Bucknell U	8	12	4	—	31	2	—
Butler U	5	13	3	—			
California Institute of Tech	14	5	4	30	6	17	6
California Polytech State U	16	45	—	—			
California State Polytech U	5	16	7	—	34	—	—
California State U							
Bakersfield	3	8	—	—			
Chico	0	13	—	—			
Dominguez Hills	5	0	—	—			
Fresno	15	11	5	—			
Fullerton	4	27	5	—			
Hayward	7	14	2	—			
Long Beach	5	45	4	—	(a)		
Los Angeles	9	10	9	—			
Northridge	8	18	4	—			
Sacramento	12	20	7	—			
San Bernardino	1	9	—	—			
Stanislaus	2	4	—	—			
California, U of							
Berkeley	23	39	8	54	84	13	19
Davis	41	16	3	20	(a)		
Irvine	12	52	13	23			
Los Angeles	13	139	12	41	30	9	4
Riverside	10	3	2	5			
San Diego	69	1	19	35	18	0	2
Santa Barbara	10	6	8	8	(a)		
Santa Cruz	3	14	1	7			
Calvin C	1	10	—	—			
Canisius C	3	3	—	—			
Capital U	0	2	—	—			
Carleton C	9	15	—	—			
Carnegie Mellon U	15	4	5	6	44	6	16
Carroll C	1	5	—	—			
Carthage C	1	1	—	—			
Case Western Reserve U	5	33	10	8	30	3	7
Catholic U of America	1	3	3	2			
Centenary C of Louisiana	0	2	—	—			
Central Connecticut State U	5	0	1	—			
Central Florida, U of	11	0	5	—			
Central Michigan U	4	13	8	—			
Central Oklahoma, U of	4	5	—	—			
Central State U	1	5	—	—			
Central U of Iowa	1	4	—	—			
Centre C	0	0	—	—			
Charleston, C of	10	24	—	—			
Chatham C	3	0	—	—			
Chestnut Hill C	0	3	—	—			
Chicago State U	0	9	—	—			
Chicago, U of	11	9	7	23			
Christian Brothers U[b]					(a)		
Cincinnati, U of	26	0	16	24	43	8	2
Citadel, The	0	2	—	—			
City U of New York							
Graduate Center				28			
Brooklyn C	1	26	6	—			
City C	0	17	30	—	(a)		
Herbert H. Lehman C	8	0	—	—			
Hunter C	0	11	—	—			
Queens C	0	20	2	—			
Clarion U	6	2	—	—			
Clark U	6	8	3	4			
Clarkson U	4	2	6	10	50	5	5
Clemson U	5	3	3	8	39	7	1
Cleveland State U	12	0	8	5	(a)		
Coe C	1	4	—	—			
Colby C	2	5	—	—			
Colgate U	8	7	—	—			
Colorado C	11	1	—	—			
Colorado School of Mines	3	0	4	6	51	2	4
Colorado State U	11	5	2	10	9	5	4
Colorado, U of							
Boulder	7	45	7	21	42	13	13
Colorado Springs	3	1	—	—			
Denver	6	6	0	—			
Columbia U	9	10	11	15	(a)		
Concordia C	3	4	—	—			
Connecticut C	0	4	—	—			
Connecticut, U of	10	7	11	8	23	3	0
Cooper Union[b]					(a)		

	CHEMISTRY				CHEMICAL ENGINEERING		
	Bachelor's certified						
	Yes	No	M.S.	Ph.D.	B.S.	M.S.	Ph.D.
Cornell C	0	9	—	—			
Cornell U	7	35	46	26	51	11	6
Creighton U	22	1	—	—			
Dartmouth C	0	29	2	3			
David Lipscomb U	1	14	—	—			
Davidson C	1	8	—	—			
Dayton, U of	2	4	1	—	32	3	—
Delaware State U	4	1	4	—			
Delaware Valley C of Science & Agriculture	11	0	—	—			
Delaware, U of	25	13	5	16	37	10	23
Delta State U	1	11	—	—			
Denison U	4	1	—	—			
Denver, U of	1	3	2	0			
DePaul U	2	8	12	—			
DePauw U	0	9	—	—			
Detroit Mercy, U of	4	3	17	6	13	10	1
Dickinson C	0	4	—	—			
District of Columbia, U of the	3	2	—	—			
Drake U	0	1	—	—			
Drew U	1	2	—	—			
Drexel U	6	0	6	4	(a)		
Duke U	8	25	3	14			
Duquesne U	3	5	4	1			
Earlham C	0	11	—	—			
East Carolina U	5	4	6	—			
East Stroudsburg U	6	6	0	—			
East Tennessee State U	7	13	4	—			
East Texas State U	0	5	1	—			
Eastern Illinois U	6	3	2	—			
Eastern Kentucky U	2	11	4	—			
Eastern Michigan U	7	22	11	—			
Eastern New Mexico U	3	6	2	—			
Eastern Washington U	0	13	2	—			
Eckerd C	0	2	—	—			
Elizabethtown C	1	6	—	—			
Elmhurst C	1	11	—	—			
Emory U	2	39	5	20			
Emporia State U	3	3	1	—			
Evansville, U of	4	5	—	—			
Fairfield U	5	1	—	—			
Fairleigh Dickinson U							
Madison	2	0	1	—			
Teaneck	1	1	1	—			
Fisk U	6	6	1	—			
Florida A&M U	0	1	0	—			
Florida A&M U/ Florida State U[b]					22	1	1
Florida Atlantic U	7	15	5	—			
Florida Institute of Tech	1	4	0	0	(a)		
Florida International U	4	15	2	—			
Florida State U	6	35	7	8			
Florida, U of	9	27	6	26	34	3	10
Fordham U	0	10	—	—			
Fort Lewis C	3	9	—	—			
Framingham State C	7	0	—	—			
Franklin & Marshall C	9	3	—	—			
Furman U	25	0	7	—			
Geneva C	2	8	—	—			
George Mason U	11	2	5	0			
George Washington U	1	11	0	2			
Georgetown U	14	0	11	10			
Georgia Institute of Tech	29	0	13	17	84	11	12
Georgia Southern U	1	2	—	—			
Georgia State U	0	8	4	3			
Georgia, U of	9	14	5	12			
Gettysburg C	8	3	—	—			
Gonzaga U	4	2	—	—			
Goucher C	3	4	—	—			
Grand Valley State U	2	10	—	—			
Grinnell C	4	12	—	—			
Gustavus Adolphus C	0	15	—	—			
Hamilton C	1	3	—	—			
Hamline U	8	1	—	—			
Hampden-Sydney C	8	1	—	—			
Hampton U	6	0	0	—			
Hartford, U of	1	1	0	—			
Hartwick C	1	6	—	—			
Harvard U	20	3	26	40			
Harvey Mudd C	10	0	—	—			
Haverford C	10	1	—	—			
Hawaii, U of	8	10	4	9			
Hendrix C	4	0	—	—			
Hiram C	5	3	—	—			
Hobart & William Smith C	2	3	—	—			
Hofstra U	3	1	—	—			
Hollins C	0	3	—	—			
Holy Cross, C of the	18	4	—	—			
Hope C	21	13	—	—			
Houston, U of	8	1	5	14	37	14	6
Howard U	2	25	1	9	14	2	—
Humboldt State U	3	3	—	—			
Idaho State U	4	3	—	—			
Idaho, U of	4	6	8	5	24	12	2
Illinois Benedictine C	6	1	—	—			
Illinois Institute of Tech	3	0	6	1	29	10	3
Illinois State U	48	4	12	—			
Illinois Wesleyan U	4	0	—	—			
Illinois, U of							
Chicago	13	34	7	10	23	14	5
Urbana-Champaign	34	69	16	26	68	10	8
Indiana State U	7	1	1	—			
Indiana U-Purdue U							
Fort Wayne	5	4	0	—			
Indianapolis	6	14	9	1			
Indiana U							
Bloomington	32	117	10	29			
Northwest	2	1	—	—			
South Bend	3	0	—	—			
Southeast	2	9	—	—			
Indiana U of Pennsylvania	5	2	4	—			
Interamerican U of Puerto Rico	4	8	—	—			
Iowa State U	9	5	5	30	33	3	9
Iowa, U of	16	2	12	23	15	1	1
Ithaca C	8	5	—	—			
Jackson State U	5	9	2	—			
James Madison U	6	18	—	—			
John Carroll U	3	15	3	—			
Johns Hopkins U	21	0	21	16	13	4	5
Juniata C	4	7	—	—			
Kalamazoo C	4	10	—	—			
Kansas State U	5	8	4	8	23	5	0
Kansas, U of	2	18	4	7	26	4	1
Kean C of New Jersey	3	5	—	—			
Kennesaw State C	1	4	—	—			
Kent State U	15	13	1	7			
Kentucky, U of	7	9	3	7	22	4	2
Kenyon C	5	6	—	—			
King's C	2	0	—	—			
Knox C	1	17	—	—			
La Salle U	7	2	—	—			
Lafayette C	3	5	—	—	18	—	—
Lake Forest C	2	1	—	—			
Lamar U	4	2	6	—	(a)		
Lawrence Technological U	9	0	—	—			
Lawrence U	2	8	—	—			
LeMoyne C	4	0	—	—			

	CHEMISTRY				CHEMICAL ENGINEERING		
	Bachelor's certified						
	Yes	No	M.S.	Ph.D.	B.S.	M.S.	Ph.D.
Lebanon Valley C	3	2	—	—			
Lehigh U	2	2	15	11	29	8	5
Lewis & Clark C	0	5	—	—			
Lincoln U	1	15	—	—			
Long Island U							
Brooklyn Campus	0	0	5	—			
C. W. Post Campus	1	0	—	—			
Loras C	1	3	—	—			
Louisiana State U							
Baton Rouge	6	5	5	7	42	15	1
Shreveport	0	5	—	—			
Louisiana Tech U	1	4	4	—	20	5	3
Louisville, U of	15	9	1	5	(a)		
Loyola C in Maryland	1	0	—	—			
Loyola Marymount U	1	0	—	—			
Loyola U							
Chicago	8	3	5	3			
New Orleans	4	2	—	—			
Luther C	0	6	—	—			
Lycoming C	2	0	—	—			
Macalester C	4	6	—	—			
Maine, U of	4	1	2	6	38	4	0
Manhattan C[c]	4	5	—	—	14	9	—
Mankato State U	6	10	1	—			
Marietta C	1	1	—	—			
Marist C	4	0	—	—			
Marquette U	8	0	6	5			
Marshall U	3	21	3	—			
Maryland, U of							
Baltimore County	9	35	6	5	14	6	3
College Park	3	37	5	11	(a)		
Massachusetts Institute of Tech	33	0	4	51	(a)		
Massachusetts, U of							
Amherst	17	3	6	12	20	6	7
Boston	2	21	1	—			
Dartmouth	0	10	3	—			
Lowell	2	8	6	19	12	7	—
McNeese State U	0	0	4	—			
Memphis, U of	1	9	4	2			
Mercer U	1	4	—	—			
Merrimack C	8	1	—	—			
Metropolitan State C	3	17	—	—			
Miami U	11	27	3	7			
Miami, U of	6	11	2	5			
Michigan State U	26	10	9	25	(a)		
Michigan Technological U	11	0	6	1	(a)		
Michigan, U of							
Ann Arbor	56	0	10	20	86	17	7
Dearborn	10	11	—	—			
Flint	2	12	—	—			
Middle Tennessee State U	3	24	2	0			
Middlebury C	0	11	—	—			
Midwestern State U	5	4	—	—			
Millersville U	3	9	—	—			
Millikin U	7	4	—	—			
Millsaps C	5	10	—	—			
Minnesota, U of							
Duluth	8	17	3	—	16	—	—
Minneapolis	32	0	7	39	101	7	30
Mississippi C	4	6	—	—			
Mississippi State U	2	4	2	3	(a)		
Mississippi, U of	7	6	6	4	11	7	0
Missouri, U of							
Columbia	9	4	6	9	36	10	1
Kansas City	3	16	6	1			
Rolla	13	0	8	6	(a)		
St. Louis	8	12	12	4			
Missouri Western State C	4	4	—	—			
Monmouth C	3	0	—	—			
Montana C of Mineral Science & Tech	3	3	1	—			
Montana State U	1	5	3	11	(a)		
Montana, U of	2	5	1	2			
Montclair State C	2	6	4	—			
Moorhead State U	2	3	—	—			
Moravian C	0	0	—	—			
Morehouse C	5	1	—	—			
Morgan State U	8	6	—	—			
Mount Holyoke C	7	0	0	—			
Mount Saint Vincent, C of[c]	0	1	—	—			
Muhlenberg C	5	2	—	—			
Murray State U	3	11	4	—			
Muskingum C	0	3	—	—			
Nazareth C	1	0	—	—			
Nebraska Wesleyan U	2	3	—	—			
Nebraska, U of							
Kearney	1	11	—	—			
Lincoln	2	8	10	11	15	9	1
Omaha	2	1	—	—			
Nevada, U of							
Las Vegas	3	5	2	—			
Reno	2	4	3	3	(a)		
New Hampshire, U of	7	2	3	7	15	4	3
New Jersey Institute of Tech[b]					(a)		
New Mexico Highlands U	0	4	1	—			
New Mexico Institute of Mining & Tech	5	0	3	2			
New Mexico State U	0	18	3	3	(a)		
New Mexico, U of	12	4	4	9	9	11	3
New Orleans, U of	2	7	5	9			
New York U	1	26	11	12			
Niagara U	1	1	—	—			
North Alabama, U of	8	9	—	—			
North Carolina A&T State U	4	0	4	—	18	—	—
North Carolina Central U	0	6	1	—			
North Carolina State U	25	65	5	7	(a)		
North Carolina, U of							
Asheville	2	3	—	—			
Chapel Hill[d]	32	47	11	40			
Charlotte	6	5	2	—			
Greensboro	4	6	1	—			
Wilmington	4	17	0	—			
North Dakota State U	3	15	5	9			
North Dakota, U of	2	5	1	1	20	4	—
North Texas, U of	7	4	10	7			
Northeast Louisiana U	5	0	3	—			
Northeast Missouri State U	17	0	—	—			
Northeastern Illinois U	0	8	4	—			
Northeastern U	7	0	6	3	(a)		
Northern Arizona U	10	17	11	—			
Northern Colorado, U of	3	7	1	2			
Northern Illinois U	8	5	10	5			
Northern Iowa, U of	11	14	0	—			
Northern Kentucky U	0	8	—	—			
Northern Michigan U	1	14	0	—			
Northwest Missouri State U	3	4	—	—			
Northwestern State U of Louisiana	0	0	—	—			
Northwestern U	15	17	40	36	43	8	19
Notre Dame, U of	7	13	4	9	31	12	5
Oakland U	3	0	2	1			
Oberlin C	10	19	—	—			
Occidental C	6	9	—	—			
Ohio Northern U	10	4	—	—			
Ohio State U	27	8	21	33	(a)		
Ohio U	7	15	3	4	26	5	2

	CHEMISTRY				CHEMICAL ENGINEERING		
	Bachelor's certified						
	Yes	No	M.S.	Ph.D.	B.S.	M.S.	Ph.D.
Ohio Wesleyan U	2	11	—	—			
Oklahoma State U	4	3	1	7	21	10	2
Oklahoma, U of	11	19	8	10	26	9	2
Old Dominion U	5	11	6	—			
Oregon State U	16	2	8	10	(a)		
Oregon, U of	7	29	12	12			
Pace U							
New York	1	2	—	—			
Pleasantville	2	4	—	—			
Pacific Lutheran U	2	10	—	—			
Pacific, U of the	0	5	2	2			
Pennsylvania State U	17	9	8	28	113	5	8
Pennsylvania, U of	0	23	3	17	20	7	9
Philadelphia C of Pharmacy & Science	2	3	0	2			
Philadelphia C of Textiles & Science	2	1	—	—			
Pittsburg State U	3	7	4	—			
Pittsburgh, U of	12	50	12	23	(a)		
Polytechnic U	1	0	11	7	(a)		
Pomona C	4	8	—	—			
Portland State U	0	9	3	4			
Portland, U of	2	1	—	—			
Princeton U	16	8	0	17	(a)		
Providence C	1	3	—	—			
Puerto Rico, U of							
Mayaguez	8	23	2	—	(a)		
Rio Piedras	10	12	8	4			
Puget Sound, U of	6	4	—	—			
Purdue U	18	25	11	43	117	10	18
Purdue U Calumet	5	2	—	—			
Ramapo C of New Jersey	6	0	—	—			
Randolph-Macon C	0	6	—	—			
Randolph-Macon Women's C	1	1	—	—			
Redlands, U of	0	3	—	—			
Reed C	7	8	—	—			
Rensselaer Polytechnic Institute	6	0	12	8	54	15	12
Rhode Island C	1	4	—	—			
Rhode Island, U of	5	2	2	2	8	2	3
Rhodes C	3	7	—	—			
Rice U	7	13	9	12	12	7	6
Richmond, U of	0	15	—	—			
Rider C	6	0	—	—			
Ripon C	3	2	—	—			
Roanoke C	3	2	—	—			
Rochester Institute of Tech	19	7	5	—			
Rochester, U of	7	3	24	14	22	5	9
Rockhurst C	1	4	—	—			
Rollins C	1	0	—	—			
Roosevelt U	9	0	3	—			
Rose-Hulman Institute of Tech	6	0	—	—	26	0	—
Rowan C of New Jersey	7	4	—	—			
Russell Sage C	2	0	—	—			
Rutgers U							
Camden C	3	4	—	—			
New Brunswick	12	27	12	15	34	8	3
Newark C	5	3	5	9			
Saginaw Valley State U	5	16	—	—			
St. Anselm C	3	0	—	—			
St. Benedict, C of/ St. John's U	4	11	—	—			
St. Catherine, C of	2	3	—	—			
St. Cloud State U	2	7	—	—			
St. John Fisher C	5	6	—	—			
St. John's U	2	1	4	—			
St. Joseph C	0	1	5	—			
St. Joseph's U	6	6	7	—			
St. Lawrence U	2	7	—	—			
St. Louis U	7	18	3	—			
St. Mary's C	0	0	—	—			
St. Michael's C	3	2	—	—			
St. Olaf C	2	46	—	—			
St. Peter's C	1	1	—	—			
St. Thomas, U of	4	12	—	—			
St. Vincent C[a]	5	0	—	—			
Salem State C	12	0	—	—			
Salisbury State U	3	2	—	—			
Sam Houston State U	3	15	6	—			
San Diego State U	17	5	8	3			
San Diego, U of	0	7	—	—			
San Francisco State U	8	26	8	—			
San Francisco, U of	11	0	1	—			
San Jose State U	10	11	3	—	(a)		
Sangamon State U	2	2	—	—			
Santa Clara U	2	4	—	—			
Scranton, U of	4	10	12	—			
Seattle U	0	3	—	—			
Seton Hall U	4	4	9	2			
Seton Hill C[a]	4	0	—	—			
Shippensburg U	5	3	0	—			
Siena C	3	0	—	—			
Simmons C	0	5	—	—			
Skidmore C	0	10	—	—			
Smith C	5	4	—	—			
Sonoma State U	0	10	—	—			
South Alabama, U of[b]					17	5	—
South Carolina, U of	5	21	5	23	19	9	0
South Dakota School of Mines & Tech	3	0	2	—	24	4	—
South Dakota State U	0	27	5	2			
South Dakota, U of	4	5	4	—			
South Florida, U of	17	55	7	4	(a)		
Southeast Missouri State U	0	9	—	—			
Southeastern Louisiana U	3	0	—	—			
Southern California, U of	15	6	1	11	12	17	2
Southern Colorado, U of	1	3	1	—			
Southern Illinois U							
Carbondale	8	5	9	9			
Edwardsville	14	13	9	—			
Southern Methodist U	6	9	1	—			
Southern Mississippi, U of	2	19	0	4			
Southern Oregon State C	3	2	—	—			
Southern U and A&M C	10	1	5	—			
Southwest Missouri State U	5	19	—	—			
Southwest State U	2	5	—	—			
Southwest Texas State U	11	0	2	—			
Southwestern Louisiana, U of	1	3	2	—	8	6	—
Southwestern Oklahoma State U	1	8	—	—			
Stanford U	7	8	3	30	13	10	8
State U of New York							
Albany	15	0	3	4			
Binghamton	10	10	3	4			
Buffalo	9	5	4	26	32	4	2
Stony Brook	17	23	9	19			
C at Brockport	3	2	—	—			
C at Buffalo	1	11	1	—			
C at Cortland	3	4	—	—			
C at Fredonia	10	2	2	—			
C at Geneseo	2	4	—	—			
C at New Paltz	4	5	5	—			
C at Oneonta	1	13	—	—			
C at Oswego	15	6	4	—			
C at Plattsburgh	5	6	1	—			
C at Potsdam	3	5	—	—			
C at Purchase	3	2	—	—			

	CHEMISTRY				CHEMICAL ENGINEERING		
	Bachelor's certified						
	Yes	No	M.S.	Ph.D.	B.S.	M.S.	Ph.D.
Stephen F. Austin State U	1	5	1	—			
Stetson U	0	1	—	—			
Stevens Institute of Tech	16	0	14	2	14	18	2
Stockton C of New Jersey	6	4	—	—			
Suffolk U	0	7	—	—			
Susquehanna U	1	2	—	—			
Swarthmore C	5	10	—	—			
Syracuse U	8	1	4	6	11	3	3
Temple U	2	19	6	7			
Tennessee Technological U	3	14	5	—	35	5	1
Tennessee, U of							
Chattanooga	20	27	—	—			
Knoxville	1	11	7	10	34	6	7
Martin	2	5	—	—			
Texas A&M U							
College Station	16	10	4	44	75	17	11
Kingsville	7	0	1	—	24	10	—
Texas Christian U	3	11	0	4			
Texas Southern U	5	3	7	—			
Texas Tech U	17	30	4	12	(a)		
Texas, U of							
Arlington	3	10	4	6			
Austin	75	0	5	32	(a)		
Dallas	7	0	5	1			
El Paso	4	0	6	—			
Texas Woman's U	0	6	4	—			
Thiel C	0	3	—	—			
Toledo, U of	6	7	4	3	19	4	1
Towson State U	3	10	—	—			
Trenton State C	22	0	—	—			
Tri-State U[b]					8	—	—
Trinity C	6	3	0	—			
Trinity U	19	0	—	—			
Tufts U	0	14	5	4	(a)		
Tulane U	0	17	2	5	(a)		
Tulsa, U of	4	0	—	—	(a)		
Tuskegee U	0	6	0	—	24	—	—
Union C	3	3	—	—			
U.S. Air Force Academy	23	1	—	—			
U.S. Naval Academy	22	0	—	—			
Ursinus C	5	1	—	—			
Utah State U	9	0	5	5			
Utah, U of	3	27	6	9	23	1	8
Valparaiso U	5	20	—	—			
Vanderbilt U	2	28	13	8	24	5	3
Vassar C	1	0	0	—			
Vermont, U of	9	0	0	6			
Villanova U	6	0	9	3	37	10	—
Virginia Commonwealth U	4	20	0	3			
Virginia Military Institute	6	0	—	—			
Virginia Polytechnic Institute & State U	24	30	6	20	50	0	2
Virginia, U of	(a)				31	23	3
Wabash C	4	5	—	—			
Wagner C	4	0	—	—			
Wake Forest U	6	11	0	4			
Washburn U of Topeka	0	6	—	—			
Washington C	1	0	—	—			
Washington State U	12	4	7	2	22	7	0
Washington U	2	24	7	10	39	9	6
Washington & Jefferson C	2	10	—	—			
Washington & Lee U	0	17	—	—			
Washington, U of	26	43	15	23	54	2	10
Wayne State U	10	29	3	23	36	19	4
Waynesburg C	2	1	—	—			
Weber State U	5	5	—	—			
Wellesley C	11	18	—	—			
Wesleyan U	6	3	0	6			
West Chester U	4	17	5	—			
West Florida, U of	5	4	—	—			
West Virginia Institute of Tech[b]					13	—	—
West Virginia State C	1	5	—	—			
West Virginia U	7	32	3	3	27	4	3
Western Illinois U	0	3	7	—			
Western Kentucky U	5	37	5	—			
Western Maryland C	0	6	—	—			
Western Michigan U	4	9	3	1			
Western Washington U	12	10	2	—			
Westminster C	0	5	—	—			
Wheaton C							
Illinois	5	7	—	—			
Massachusetts	2	6	—	—			
Whitman C	0	10	—	—			
Whittier C	0	8	—	—			
Wichita State U	1	10	1	3			
Widener U	1	3	—	—	(a)		
Wilkes U	1	1	—	—			
Willamette U	0	11	—	—			
William Paterson C of New Jersey	0	4	—	—			
William & Mary, C of	39	11	8	—			
Williams C	3	30	—	—			
Winona State U	1	4	—	—			
Wisconsin, U of							
Eau Claire	6	20	—	—			
Green Bay	0	9	—	—			
La Crosse	5	11	—	—			
Madison	33	0	8	37	(a)		
Milwaukee	2	14	7	3			
Oshkosh	6	6	—	—			
Parkside	10	0	—	—			
Platteville	0	2	—	—			
River Falls	6	5	—	—			
Stevens Point	4	10	—	—			
Superior	4	1	—	—			
Wittenberg U	3	5	—	—			
Wooster, C of	2	14	—	—			
Worcester Polytechnic Institute	5	3	0	2	31	1	4
Wright State U	15	2	14	—			
Wyoming, U of	4	2	0	2	16	4	0
Xavier U	3	5	—	—			
Xavier U of Louisiana	1	33	—	—			
Yale U	0	17	17	20	6	10	1
Youngstown State U	5	30	2	—	7	—	—
TOTALS	3,605	5,195	1,683	2,140	3,164	705	435

Note: For brevity, "B.S." and "M.S." are used to denote all bachelor's and master's degrees, respectively, in each column. **a** Data not submitted. **b** Listed on basis of accreditation by AIChE-ABET. **c** The chemistry programs at Mount Saint Vincent and Manhattan College are integrated into a combined department with instruction in chemistry located at Manhattan College. **d** UNC, Chapel Hill, Curriculum in Applied Sciences degrees are combined with the chemistry department degrees. **e** Saint Vincent College and Seton Hill College are integrated into a combined department.

UCLA, Berkeley top producers of chemists

The University of California, Los Angeles; Cornell University; and the University of California, Berkeley, were, in that order, the largest producers of new bachelor's, master's, and Ph.D. chemists in the 1992–93 academic year.

The total number of new bachelor's degree chemists was up 4.3% to 8,800. This trend is now three years old, but numbers are still off from the high reached in 1984–85, when there were 9,679 such graduates. The number of Ph.D.s dropped for the second year in a row, down nearly 3%.

These are some of the notable points in the latest report of ACS's Committee on Professional Training (CPT). CPT gathers graduation data annually from chemistry departments with undergraduate programs it has approved. These departments account for about 90% of all new bachelor's degree chemists and for essentially all advanced chemistry degrees.

In 1992–93, UCLA moved up from third position to edge out the 1991–92 leader, Indiana University, Bloomington, for the top spot as largest producer of B.S. chemists. North Carolina State University took the third slot in 1992–93, while the University of Illinois, Urbana-Champaign, dropped from second to fourth.

Cornell regained the top spot as the largest producer of master's graduates. It was followed by Northwestern University, which rose from sixth place in 1991–92. City University of New York, City College, rose from 24th place in 1991–92 to take third place. Johns Hopkins University, the top master's producing school in 1991–92, dropped to sixth.

Last year was the ninth consecutive year that UC Berkeley headed the list of Ph.D. producers. Massachusetts Institute of Technology moved up three places to the second spot, followed by Texas A&M University, up five places to the third spot. Illinois, the 1991–92 second-place school, dropped to 20th place.

The University of Texas, Austin, retained its status as the largest producer of certified bachelor's graduates. UC San Diego and the University of Michigan, Ann Arbor, came in second and third, respectively, in the current report. Those who complete an approved curriculum are immediately eligible for ACS membership.

Linda Ross

These schools had the most chemistry graduates, 1992-93

Total bachelor graduates

1.	U of California, Los Angeles	152
2.	Indiana U, Bloomington	149
3.	North Carolina State U	110
4.	U of Illinois, Urbana-Champaign	103
5.	U of North Carolina, Chapel Hill	79
6.	U of Texas, Austin	75
7.	U of South Florida	72
8.	U of California, San Diego	70
9.	U of Washington	69
10.	U of California, Irvine	64
11.	U of California, Berkeley	62
11.	U of Pittsburgh	62
13.	California Poly State U	61
14.	U of California, Davis	57
15.	U of Michigan, Ann Arbor	56
16.	Virginia Poly Inst & State U	54
17.	U of Colorado, Boulder	52
17.	Illinois State U	52
19.	California State U, Long Beach	50
19.	C of William & Mary	50
21.	St. Olaf C	48
22.	U of Illinois, Chicago	47
22.	U of Tennessee, Chattanooga	47
22.	Texas Tech U	47
25.	U of Maryland, Baltimore County	.4

Certified bachelor graduates

1.	U of Texas, Austin	75
2.	U of California, San Diego	69
3.	U of Michigan, Ann Arbor	56
4.	Illinois State U	48
5.	U of California, Davis	41
6.	C of William & Mary	39
7.	U of Illinois, Urbana-Champaign	34
8.	Massachusetts Inst of Tech	33
8.	U of Wisconsin, Madison	33
10.	Indiana U, Bloomington	32
10.	U of Minnesota, Minneapolis	32
10.	U of North Carolina, Chapel Hill	32
13.	Georgia Tech U	29
14.	Ohio State U	27
15.	U of Cincinnati	26
15.	Michigan State U	26
15.	U of Washington	26
18.	U of Delaware	25
18.	Furman U	25
18.	North Carolina State U	25
21.	Virginia Poly Inst & State U	24
22.	U of California, Berkeley	23
22.	U.S. Air Force Academy	23
24.	Creighton U	22
24.	Trenton State C	22
24.	U.S. Naval Academy	22

Master graduates

1.	Cornell U	46
2.	Northwestern U	40
3.	City U of New York, City C	30
4.	Harvard U	26
5.	U of Rochester	24
6.	Johns Hopkins U	21
6.	Ohio State U	21
8.	U of California, San Diego	19
9.	U of Detroit, Mercy	17
9.	Yale U	17
11.	U of Cincinnati	16
11.	U of Illinois, Urbana-Champaign	16
13.	Lehigh U	15
13.	U of Washington	15
15.	Stevens Inst of Tech	14
15.	Wright State U	14
17.	U of California, Irvine	13
17.	Georgia Southern U	13
17.	Vanderbilt U	13
20.	U of California, Los Angeles	12
20.	DePaul U	12
20.	Illinois State U	12
20.	U of Iowa	12
20.	U of Missouri, St. Louis	12
20.	U of Oregon	12
20.	U of Pittsburgh	12
20.	Rensselaer Poly Inst	12
20.	Rutgers U, New Brunswick	12
20.	U of Scranton	12

Doctoral graduates

1.	U of California, Berkeley	54
2.	Massachusetts Inst of Tech	51
3.	Texas A&M U	44
4.	Purdue U	43
5.	U of California, Los Angeles	41
6.	Harvard U	40
6.	U of North Carolina, Chapel Hill	40
8.	U of Minnesota, Minneapolis	39
9.	U of Wisconsin, Madison	37
10.	Northwestern U	36
11.	U of California, San Diego	35
12.	Ohio State U	33
13.	U of Texas, Austin	32
14.	California Inst of Tech	30
14.	Iowa State U	30
14.	Stanford U	30
17.	Indiana U, Bloomington	29
18.	City U of New York, Grad Center	28
18.	Pennsylvania State U	28
20.	Cornell U	26
20.	U of Florida	26
20.	U of Illinois, Urbana-Champaign	26
20.	Michigan State U	26
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CHEMICAL & ENGINEERING NEWS

C&EN

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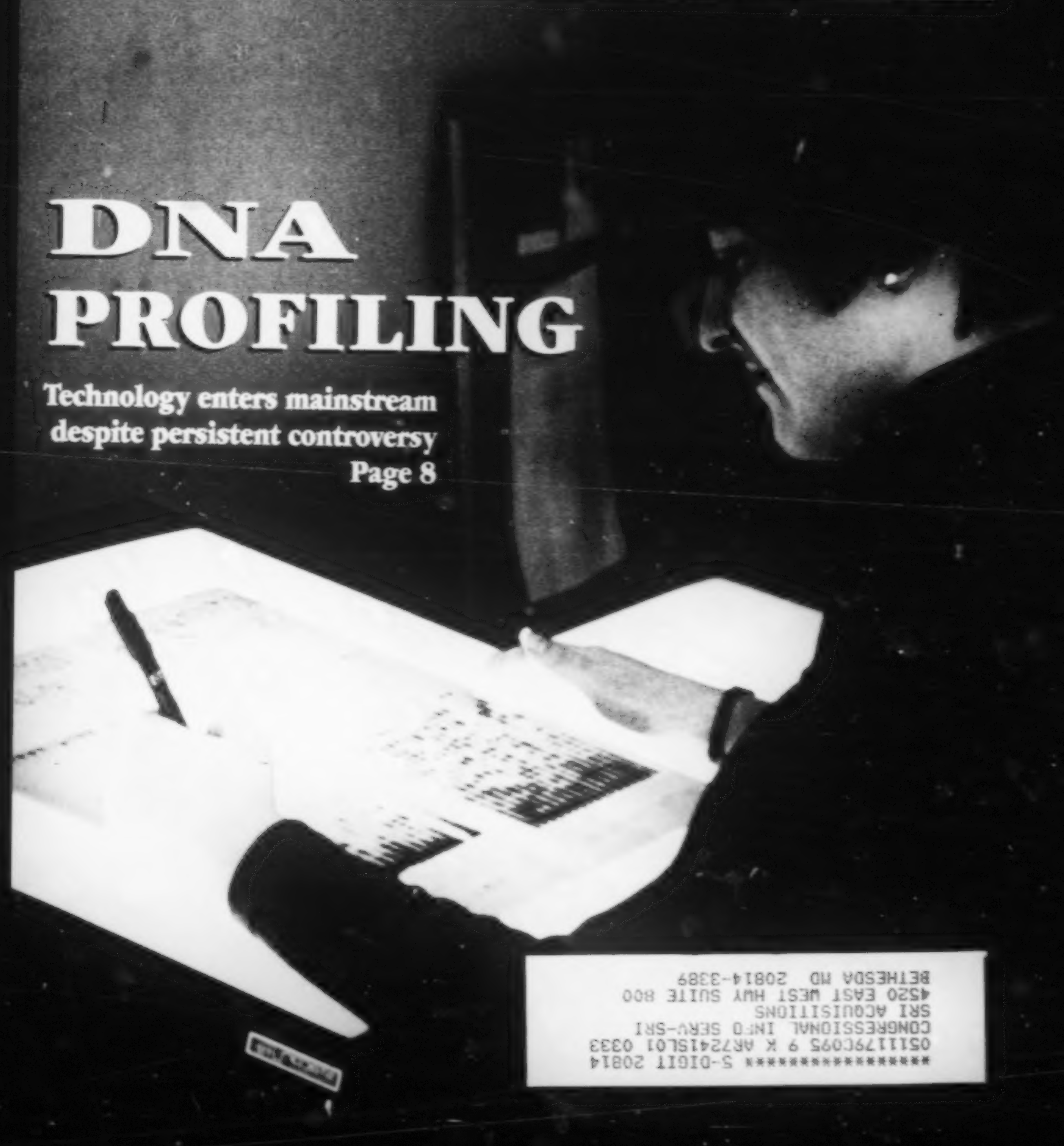
APPLICATIONS SEEN FOR ORGANOMETALLIC CATALYSIS IN AQUEOUS MEDIA PAGE 28

DNA PROFILING

Technology enters mainstream despite persistent controversy
Page 8



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CHEMICAL & ENGINEERING NEWS

C&EN

OCTOBER 10, 1994

NEWS OF THE WEEK

- IUPAC releases its recommended names for elements 101 to 109, rekindling long-running controversy and rejecting name "seaborgium" for element 106. Page 4
- Antarctic ozone hole appeared earlier than usual this year, and it's larger than expected. Page 5
- Restructuring in the pharmaceutical industry leads to loss of jobs for chemists at former Sterling Winthrop R&D center and at Carter-Wallace sites. Page 5
- Bills renewing Superfund are declared dead for this year in the House and Senate. Page 6
- Hoechst Celanese announces plans to double its North American polyethylene terephthalate capacity by 1998. Page 6
- Spent nuclear fuel rods reach Department of Energy storage facilities in South Carolina after failure of state's suit to block their entry from abroad. Page 7
- Department of Defense unveils strategic plan to maintain U.S. superiority in defense-related technology. Page 7

COVER: Cellmark Diagnostics employee scores DNA profile for a paternity case

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BUSINESS

Keith McKennon, recipient of the Chemical Industry Medal and recently retired chairman of Dow Corning, reflects on the chemical industry and dealing with crises. Page 17

Foreign investment in the U.S. chemical industry continues to rise, with industrial chemicals snaring the biggest share. Page 19

GOVERNMENT

Clinton's National Science & Technology Council, formed to revamp the federal policy-making process, is trying to make a "science" out of budgeting. Page 21

Congressional report on potential consequences of nuclear weapons proliferation after breakup of the Soviet Union advises aid to former Soviet nuclear scientists as a preventive measure. Page 25

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A technique to boost the ^{13}C nuclear magnetic resonance signal—called dynamic nuclear polarization—makes it possible to use ^{13}C NMR as a chromatographic detector. Page 36

Efficient purification of metallofullerenes, which are likely to have unique properties, is achieved with tetraphenylporphyrin-silica support material. Page 37

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DNA profiling is fast becoming an accepted identification tool in paternity and criminal court cases, but the legal system remains cautious about interpretation of data and accuracy of testing from a growing industry. Page 8

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LETTERS

Explosives disposal

I am writing in response to the Science/Technology Concentrate "Incineration of explosives poses threat to atmosphere" (C&EN, Aug. 15, page 33), which reports on research to be presented by Jehuda Yinon and Richard Yost. The article quite rightly points out the serious environmental impact that would result if the large quantities of obsolete explosives now being considered for demilitarization in the U.S. and abroad were to be dumped, buried, burned, or detonated in the open air. Other techniques of disposal, such as bacterial transformation and supercritical water degradation, are still in an early experimental stage. The authors "aim to determine whether combustion of explosives under different conditions can eliminate toxic product formation."

Although burning explosives in a poorly controlled manner can indeed produce incomplete combustion products, this operation, performed under proper conditions in a modern incinerator, produces no more hazardous products than incinerating other materials.

However, detonation of explosives under controlled conditions produces very much smaller quantities of undesirable products than controlled burning in an incinerator. Thus, large quantities of obsolete explosives (and propellants) can be disposed of quickly and effectively and in an environmentally and economically beneficial manner by including these energetic materials as active ingredients in commercial explosives that are designed to be oxygen-balanced to produce minimal quantities of unwanted reaction products.

The chemical reactions taking place in the high-pressure and moderate-temperature conditions prevalent in the detonation combustion of such explosives in large (8–15-inch diameter) drillholes in rock provide ideal conditions for achieving complete reaction. Such detonations produce the acceptable reaction products carbon dioxide, water, and nitrogen, with far less production of carbon monoxide, nitrogen oxides, hydrocarbons, and soot than the exhaust from modern automobiles and trucks.

Commercial explosives are used in the U.S., Russia, and Ukraine in quantities (2 million metric tons per year in the U.S. alone) that make the surplus quantities of demilitarized explosives seem almost trivial and make their addition in small percentages relatively easy.

The available quantities of explosives and propellants to be demilitarized really represent a considerable asset to the country and its taxpayers. Why waste the value of these products when many of them can be used in an acceptable and profitable manner as components in commercial explosives as indicated? New Mexico Tech is currently seeking funding for a research program to support safe operation in large-scale mining with explosives containing demilitarized materials. Several private companies are pursuing this approach to reuse of the large quantity of bulk explosives and propellants becoming excess, both here and in the former Soviet Union.

Major portions, but not all, of demilitarized energetic materials are suitable for reuse this way. A small fraction of the total amount of these materials contains metal compounds, toxic smokes or dyes, or other components that must be recovered or are difficult to destroy. These are candidates for the high-cost technologies currently being developed and tested, such as supercritical water oxidation.

Douglas B. Olson
Per Anders Persson
Research Center for Energetic Materials
New Mexico Tech
Socorro

Oversupply of chemists

It is refreshing to see that the American Chemical Society has finally faced the reality of the oversupply of chemists, particularly of those at the doctoral level. Attila E. Pavlath has laid out the problem (C&EN, Sept. 12, page 46), but I submit that the solution is not likely to come from the society because the major groups that control the society—academic research universities and the chemical industry—find it in their own self-interest to keep the status quo.

How can major research universities perpetuate themselves without hordes of graduate students to do the teaching and to contribute their labor to produce publications that enhance the reputation of their mentors? Universities depend upon grants for the overhead they contribute, and, thus, a catch-22 situation results. In addition, everyone knows there are too

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Foreign share in U.S. chemicals rises again

Foreign companies have long invested in the U.S. chemical industry. The reasons they give include the large homogeneous market represented by the U.S., an educated work force, and a relatively stable labor-management relationship compared with those in many other countries.

According to the latest survey of foreign investment in the U.S. by the Commerce Department, ownership of the U.S. chemical industry by overseas companies increased almost 7.5% last year from 1992. This brings book value of those foreign-owned assets to $57.7 billion. The government calculates book value on a historical cost basis—the price paid for the assets at the time of their purchase rather than their value today.

According to the Commerce Department data, of all U.S. industry, the chemicals and allied products industry is second only to wholesale trade in terms of foreign investment. And among manufacturing industries, it has by far the largest foreign investment, almost double that for second-place machinery manufacturing.

In terms of the overall picture, the chemicals and allied products sector accounts for about 12% of foreign investment in all U.S industry and 35% of foreign investment in manufacturing companies.

And investment in chemicals and allied products continues to grow at a rate faster than those for other sectors of the economy. Between 1989 and 1993, foreign investment in chemicals grew at an average annual rate of 11%. This compares with an annual growth rate for all manufacturing of just 2.5% during the same period. And foreign investment in all industry—which includes service, financial, and petroleum sectors, as well as manufacturing—increased at an average annual rate of 4.8%.

The same pattern holds true for growth in 1993, when investment in chemicals and allied products grew 7.5% from 1992. Growth for foreign investment in manufacturing increased just 2.1% and for all industry, a much lower 4.6%.

The driving force behind the growth for chemicals in the past few years has been the worldwide consolidation of the pharmaceutical industry.

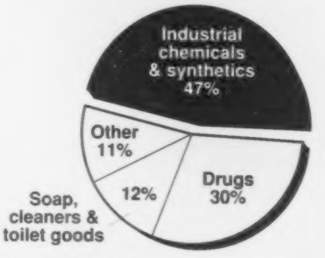
Led by deals such as the acquisition of SmithKline by Beecham of the U.K., Hoechst's acquisition of a majority of generic drugmaker Copley, and Rhône-Poulenc's acquisition of a large part of Rorer Group, foreign investment in the drug sector of the U.S. chemical industry has swelled. In 1989, the drug sector, with foreign investment of less than $9 billion, held second place in foreign investment; the third-place category was soaps, cleaners, and toilet goods at $3.6 billion in investment. However, since then, double-digit annual growth of 17.5% has almost doubled the book value of pharmaceutical investment to about $17.1 billion in 1993, increasing its lead to $10.1 billion ahead of soaps.

The largest chemical sector for foreign investment is still industrial chemicals and synthetics, just as it is the largest sector of the U.S. chemical industry. But growth of foreign investment in industrial chemicals has been slow. Between 1989 and 1993, average annual growth of book value was just 3.9% per year, bringing the value to $27.0 billion in 1993. In 1993, annual growth of 4.0% was essentially the same as the average over the past few years.

In other subcategories, investment in soaps grew at an average annual rate of 6.8% from 1989 to 1993, but was up only 2.6% from 1992 to 1993 to finish at $6.96 billion.

The agricultural chemicals sector was the star performer in terms of growth, but it was from a very small base. Agricultural chemicals ended 1993 with foreign investment of $685 million, up 32% from 1992 and up an average of 35% per year since 1989. However, investment in agricultural chemicals represented only slightly more than 1% of the total chemical investment last year.

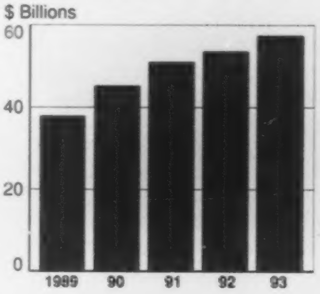
Industrial chemicals get biggest investment share



Total 1993 foreign investment in U.S. chemicals = $57.7 billion

Source: Department of Commerce

Overseas investment in chemicals up 50% since '89



Source: Department of Commerce

As in the past, European companies are by far the dominant force in investing in the U.S. chemical industry. The value of chemical holdings by European companies in 1993 totaled $51.4 billion, or almost 90% of total foreign investment in chemicals and allied products.

Traditionally, companies from the U.K. have held first place in investment, and 1993 was no exception. The book value of U.K. investment last year totaled $17.5 billion, or 30% of all foreign investment in the U.S. chemical industry. The U.K. was followed by Germany at $10.4 billion and the Netherlands at $8.64 billion.

Because of disclosure rules, the Commerce Department did not total investment for other geographic areas, except for "Latin America and other Western Hemisphere" countries, excluding Canada. U.S. chemical industry investment from countries in that group totaled $1.25 billion, or just 2.2% of the aggregate.

Although not disclosing a total for the Asia-Pacific region, the survey showed that Japanese investment in the U.S. chemical industry totaled $3.31 billion in 1993 and put investment from Taiwan at $238 million.

William Storck

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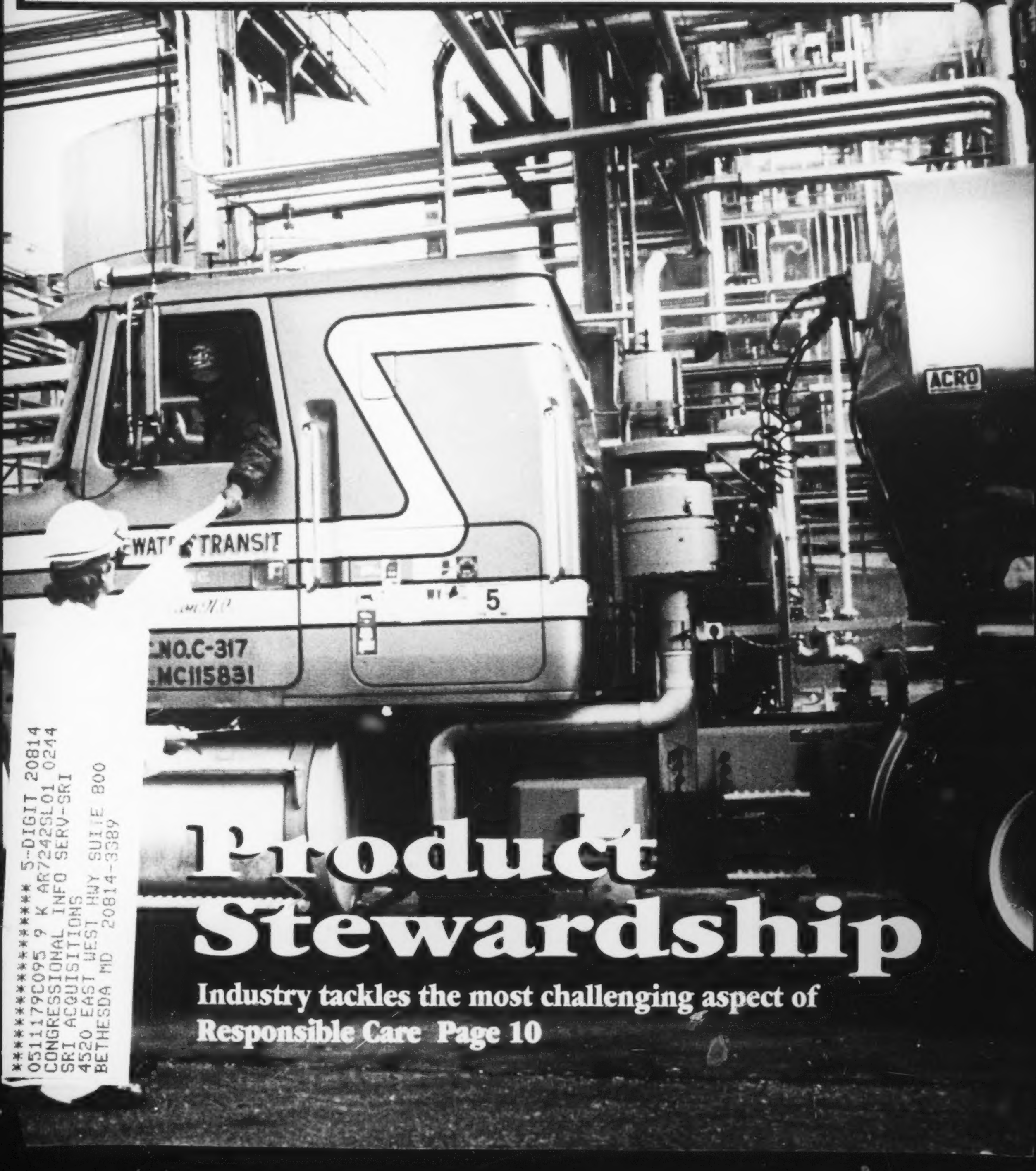
NATIONAL ENVIRONMENTAL INSTITUTE EXPANDS FOCUS BEYOND CANCER PAGE 39



Product Stewardship

Industry tackles the most challenging aspect of Responsible Care Page 10

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NEWS OF THE WEEK

- George Olah wins Nobel Prize in Chemistry for pioneering research on carbocations; Alfred Gilman and Martin Rodbell share the Nobel Prize for Physiology or Medicine for work on G-proteins. Page 4
- To settle a suit filed by environmental groups, EPA agrees to consider a ban on 36 carcinogenic pesticides under the Delaney clause; industry says outcome is far from certain. Page 5
- Congress adjourns for election campaign, letting many environmental and other bills die. Page 6
- The Society of Toxicology criticizes an Administration proposal to ban chlorine as simplistic and unmindful of toxicologic principles governing risk assessment. Page 6
- After four years orbiting and doing detailed studies of Venus, NASA spacecraft Magellan does a final experiment and takes a fatal dive into the planet's atmosphere. Page 7
- Eastman Kodak will pay penalties of $8 million for violating hazardous waste regulations and will spend tens of millions of dollars more to clean up its facilities in Rochester, N.Y. Page 7

COVER: An employee transfers documentation at a hazardous waste treatment facility. Photo courtesy of DuPont

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BUSINESS

Chemical industry executives from around the globe affirm the cost-cutting measures that have been taken and consider ways to deal with economic cycles, structural problems. **Page 35**

Corporate America's role in science education reform is growing and becoming more organized and systemic. **Page 36**

GOVERNMENT

National Institute of Environmental Health Sciences—a lesser known branch of NIH—expands the range of health effects it studies from environmental exposures beyond cancer. **Page 39**

The 1995 federal budgets approved by Congress provide no overall increase in funding for R&D agencies, but NSF and NIST receive double-digit increases. **Page 44**

SCIENCE POLICY

Comprehensive industrial competitiveness policy issued by the European Union aims for member nations to better compete with the high-tech economies of the U.S. and Japan. **Page 46**

SCIENCE/TECHNOLOGY

The wreck of the *Titanic* is providing an important laboratory setting for scientists to explore marine chemistry and how chemical techniques can help conserve artifacts. **Page 49**

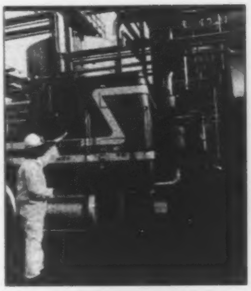
National High Magnetic Field Laboratory is formally dedicated at Florida State University in Tallahassee. **Page 52**

Organoselenium compounds that occur in low concentrations in onion and garlic have been positively identified. **Page 53**

AWARDS

ACS award winners for 1995: Comisarow, Marshall, Darensbourg, Eckert, Eliel, Engel, Fisher, Ghadiri, Grubbs, Halpern, Jencks, and Kennedy. **Page 66**

NEWS FOCUS



Product stewardship—the last Responsible Care code—challenges chemical manufacturers to work with customers and other third parties to ensure that products are handled and used safely from inception to disposal. Page 10

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LETTERS

A close look at grain ethanol

I would like to comment on the article by Deborah Illman, "Renewable Energy Lab Dedicates Ethanol Plant" (C&EN, Aug. 15, page 37). The article states that the lab will play a critical role in bringing homegrown transportation fuel produced from biomass to the U.S. marketplaces. We already have an example: grain ethanol is mandated by the Environmental Protection Agency to be in our fuels in areas of the U.S. with high carbon monoxide levels.

The following points should be noted:

- Ten percent by volume of ethanol in gasoline increases the normal vapor pressure of the gasoline by about 15%. These emissions are very reactive and easily form ozone.
- Grain ethanol, unlike ethanol made in a refinery from ethylene and water, cannot compete in the fuel market and must be subsidized. In a letter to EPA Administrator Carol Browner, California EPA administrator J. R. Strock stated that the subsidy for grain ethanol is about 54 cents per gal and will cost Californians about $60 million per year. The subsidy is paid by waiving gasoline taxes on bridges and roads, and will result in a tax increase equal to the subsidy.
- The argument that grain alcohol is a renewable fuel ignores the total energy cycle required to produce grain alcohol. The energy cycle involves the production and transportation of fertilizer, application of the fertilizer, tilling the soil, harvesting the corn, gleaning cornstarch from the corn, converting cornstarch to a sugar (yeast will not ferment cornstarch, a complex carbohydrate), and distillation of the dilute alcohol to provide 100% ethanol. All of the procedures require nonrenewable (fossil) energy greater than the renewable energy of ethanol. Similarly, more nonrenewable carbon dioxide than renewable carbon dioxide results from the energy cycle.
- Because of the undesirable properties of ethanol as a fuel, most refiners will opt to produce ethyl *tert*-butyl ether from ethanol plus isobutene. This compound, because of the subsidy, will still cost California drivers $60 million more per year than the present use of methyl *tert*-butyl ether, which does not require a methyl alcohol subsidy.
- It must be emphasized that the EPA regulation requires grain alcohol. As any chemist knows, there is no chemical difference between grain alcohol and ethanol made by chemical synthesis at a fraction of the cost.
- The argument that grain alcohol is a renewable fuel that does not increase the carbon dioxide content of the atmosphere when it is burned does not hold if the total energy cycle to form grain alcohol is included. It is abundantly clear that there is no technical argument for mandating the use of grain alcohol in our fuel supply. It is purely a political gesture toward the corn growers and Archer Daniels Midland—a mammoth conglomerate that makes grain alcohol from corn.

It is most disappointing that EPA would promulgate a regulation that financially penalizes the public and does nothing for clean air.

Alvin S. Gordon
University of California, San Diego
La Jolla

Drugs are medicine

I've been trying to get out word about this for months. The threat by the Food & Drug Administration (FDA) to regulate common tobacco products as drugs is nothing more than a public relations bluff.

It is very well established in case and administrative law that in federal law (literal reading of statutes aside) "drug" means "medicine." Materials intended only for "getting high," for example, are not drugs. The federal regulation concerning use of peyote in ceremonies of the Native American Church refers to this as "nondrug use." FDA and courts have said repeatedly that cigarettes sold for "smoking pleasure" are not drugs. Tobacco products would be drugs only if they made medical claims.

The nicotine patch and gum are drugs only because they claim to treat the "disease" of tobacco "addiction." By licensing the claims of these smoking cessation aids, FDA has for several years indicated that nicotine and tobacco "dependence" exist. The recent advisory panel's conclusion on this subject is therefore pure public relations. Anyway, dependence and addiction have no bearing on whether an article is a drug.

Robert M. Goodman
Bronx, N.Y.

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Industry Executives Seek New Ways To Cope With Business Cycles

■ ***Conference charts slow return of worldwide chemical industry into prosperity, airs concerns about restructuring***

For this year's European meeting of the London-based Society of Chemical Industry (SCI), held earlier this month in Budapest, top management delegates from countries as diverse as Hungary and Japan pondered the future of their industry, even beyond the boundaries of their own countries. One of the main conclusions: Innovative ways must be found to cope with economic cycles and to overcome fundamental structural problems that have been developing during the past decade.

As Peter Vogtländer, chemicals coordinator for Anglo-Dutch giant Shell International Chemical Co., put it in opening the conference, during the past year, companies in the European chemical industry "have cut costs and reduced manpower. There is no question that this has improved our competitive position, but in the majority of cases, it did not move our European operations to the top of the world competitive league table."

Moreover, "most of us did at least some cleaning up of our portfolio and exited from businesses in which we did not have much hope to be a successful player. We closed some capacity but fell far short of what was required. We have made less progress in this area than we should have," he says.

For the transition countries of Central and Eastern Europe, there continues to be little choice in the need to make hard decisions on the road to market economies, according to György Szapáry, deputy president of the National Bank of Hungary.

C&EN staff photo

Tashiro: high tech does not mean high profit

"We have to produce goods that are salable on the international market—we have to be competitive. We must restructure services, industries, and everything else to ensure competitiveness," he says.

Such restructuring efforts have led, he says, to a big decline in output. That decline, combined with the collapse of traditional markets in the former Soviet Union, has led to a decline in all Eastern European economies: in Hungary by somewhat more than 20% over the years 1990 to 1993 and even more in other countries.

However, since the first quarter of 1993, production has started to increase. According to Szapáry, a typical pattern exists: decline with "constructive destruction," after which new investment takes hold and production picks up. Hungary has now moved about half of its gross domestic product into the private sector, he says. "There is still a lot to do, but much has been accomplished," and privatization remains high on the government's agenda.

A case in point is the decision, announced in September, to partially privatize Richter Gedeon, the country's largest pharmaceutical company. It is one of Hungary's top five exporters, with exports of $67.3 million in first-half 1994. Total sales during first-half 1994 were $112 million, and pretax profits were $27 million. The government currently holds 87% of Richter; the remaining 13% is held by various other interests, including employees.

"Hungary's government has decided to do all these things—it is committed to them," says Szapáry. "We are condemned to succeed—there is no alternative."

In contrast to the problems of the transition countries, those of the Japanese chemical industry mirror closely those of the Western European industry. However, Japan's industry has an additional complicating factor: the close proximity of the Asian "tiger" economies, including China, says Madoka Tashiro, president and chief executive officer of Tosoh Corp., of Tokyo.

The chemical industry in the U.S. is already well on its way to a full recovery, he says. The basis of a recovery is starting to appear in Europe, and Asia is showing signs of economic activity "to the point of overheating. Only in Japan is the situation getting worse, or at least it has been so until quite recently. For example, the results before taxes of eight of the major [Japanese]

Too many product grades hurt Japan

Number of grades	Japan	U.S.	Europe	Korea	Taiwan	Saudi Arabia
Polyethylene, low density	2,500	300	500	200	60	4
Polyethylene, high density	1,000	150	150	100	30	5
Polypropylene	6,000	300	500	150	60	0

Source: Japanese Ministry for International Trade & Industry survey chemical companies in fiscal 1993 were all in the red, amounting to a combined loss of $800 million," Tashiro adds.

Prices have fallen over the past several years, but costs have not dropped commensurately. In fact, because the structure for costs such as personnel, R&D, maintenance, depreciation, interest, and environmental protection has not changed greatly, the appreciation of the yen means that costs have substantially increased compared with international levels.

"The second problem is one of our own doing and deals with high costs brought about by differentiation and diversification which prevailed in the 1980s," Tashiro says.

"Differentiation was attempted by creating numerous customer grades for even a commodity-type product and then producing only small quantities of each grade. This is especially true for plastic resins. Obviously, this led to lower productivity and also increased R&D costs," he notes.

A similar situation occurred in the area of diversification, he suggests. Electronics, biotechnology, and new products became the key words for the industry. "This naturally pushed up R&D costs significantly," he says. "The industry learned the hard way that high tech does not necessarily mean high profit or high return but does mean high costs and high risks."

Tashiro says that Japanese chemical companies are starting to focus or refocus their efforts on their core business areas where they have a clear, competitive position worldwide. And the chemical industry, along with many others in Japan, is also reevaluating its employment system. "This may not sound like anything particularly new to you, but this is a high challenge for Japan," he points out.

Whether in Japan or in Central and Eastern Europe or in Western Europe, the danger is that once negative pressures to restructure dissipate, efforts to do so will disappear as well. As Vogtländer puts it: "If [restructuring] was too difficult during the bad times, will it be any easier during the better times? Will all the good intentions forged in the fires of a crisis lose their mettle now the immediate danger is past?" A strong future for the chemical industry will depend upon those good intentions coming to pass.

Patricia Layman

Firms urged to commit to education reform

Increasingly, corporate America has been moving toward greater support of science education programs. Its motivation is both altruistic—concern about the effectiveness, or lack thereof, of U.S. science education—and self-interested—the need to increase scientific literacy and ensure a future supply of well-trained scientists and technicians. Now, that support is reaching down as far as the elementary school level.

As a means to help companies assess the effectiveness of their own programs and to develop strategies for reforming science education, the National Science Resources Center (NSRC) late last month sponsored a one-day meeting entitled "Corporate America's Impact on Elementary Science Education." NSRC is a joint effort of the National Academy of Sciences and the Smithsonian Institution aimed at systemic reform in science education, rather than "quick-fix" or piecemeal approaches.

Hosted by Merck, at its new headquarters in northwestern New Jersey, representatives from more than 70 companies—including more than 25 pharmaceutical and chemical producers—discussed the need for reforming science education, philosophies and plans for how that reform might be accomplished more consistently, and examples of existing corporate initiatives. In addition to many high-technology companies, the participants also included representatives from educational associations and foundations and from organizations such as the National Academy of Sciences, the Department of Education, and the National Research Council.

C&EN staff photo

NSRC's Shuler addresses corporate representatives on science education.

Offering examples from their own experiences were NSRC's corporate collaborators and sponsors—Bristol-Myers Squibb, Dow Chemical, Hewlett-Packard, Miles Inc., and Merck—in a panel discussion mediated by Sally Goetz Shuler, deputy director of NSRC. Merck, like many firms, initially supported higher education by funding graduate students and postdoctoral fellows, explains P. Roy Vagelos, Merck's chairman who retires Oct. 31. But recognizing that the number of people entering the pipeline was decreasing, the company has shifted the focus to earlier education to "avoid losing people early on," he adds.

The company set up the Merck Institute for Science Education in 1993. It has a minimum 10-year, $20 million commitment from Merck and is supporting numerous local community programs. "We've done many things, but we wonder how effective we are," says Vagelos, referring both to Merck and general industry efforts. "A national focus that truly identifies those areas that can be productive in teaching young people science and math would be a tremendous contribution to the U.S."

Although committed to improving the quality of science education, many companies stress the need to justify their involvement and expenditures for education. This often means gaining critical corporate management support and demonstrating that money is being spent wisely. "Philanthropy and business is business," comments Sande Deitch, executive director of the Miles Inc. Foundation at chemicals and pharmaceuticals producer Miles. "Corporations do not give money away for nothing; we're just not the shining knights."

In the short term, philanthropic efforts are a good way to get a company's name out in a positive way, but in the long term, companies depend on a skilled work force and a scientifically literate public. Miles has developed collaborative partnerships with 28 school dis-

Research generally fares poorly in '95 budgets, but NSF, NIST buck trend

Janice R. Long, C&EN Washington

The 103rd Congress managed to accomplish at least one task on time and under budget before it adjourned for the '94 fall campaign season. It enacted all 13 of the appropriations bills needed to keep the federal government operating, and it did so before fiscal-year 1995 began on Oct. 1.

Such promptness didn't translate into good news for the research community, however. Overall, Congress provided a zero budget increase for the federal agencies that fund R&D, in the process cutting President Bill Clinton's R&D budget request 1% to $79.6 billion. Nevertheless, Congress, particularly members of the House and Senate Appropriations Committees, managed, as usual, to find enough money to fund a number of specific academic research projects and programs, to the tune of tens of millions of dollars.

The Department of Defense's fiscal 1995 appropriations bill, H.R. 4650, has its share of such academic pork, at least $140 million worth as Rep. George E. Brown Jr. (D.-Calif.) pointed out during floor consideration of the House-Senate conference report on the bill. About 90% of that $140 million goes to academic projects in districts or states represented by members of the appropriations committees. Still, he admits that $140 million in identifiable earmarks represents significant progress over last year. DOD's fiscal 1994 appropriations bill contained approximately $275 million in earmarks. In addition, Brown notes, there are another eight projects worth almost $43 million that are probably going to academic institutions.

Among this year's earmarked projects are $15 million for the Tulane/Xavier Center for Bioenvironmental Research in New Orleans, a city represented by Sen. J. Bennett Johnston (D.-La.), chairman of the Appropriations Subcommittee on Energy & Water Development. (The center bears Johnston's name.) Three other Louisiana projects split $2.25 million. Hawaii, whose senior Senator, Democrat Daniel K. Inouye, chairs the Appropriations Subcommittee on Defense, fared even better. Six earmarked projects within its boundaries receive a total of $42 million. Pennsylvania, which is the home state of Inouye's House counterpart, Democrat John P. Murtha, is the recipient of four earmarked projects worth just $6 million.

Altogether H.R. 4650 provides just under $36 billion for DOD research, development, test, and evaluation programs in fiscal 1995. That amount represents a 3% increase over fiscal 1994 levels, but is 1% less than the Administration had requested. However, conferees on the bill then took back some of what they had given, directing DOD to cut $200 million from the amount just provided for support of university research programs—about $1.8 billion. The House earlier had cut the university research account by $900 million, or 50%, so a truly draconian cut was avoided.

Also on the academic front, the conference report on H.R. 4650 said, "The conferees are concerned about overhead charged by universities to Defense research contracts, particularly the amount the DOD must pay annually to universities for overhead, about $500 million, and the variability of overhead rates applied to each institution's research projects." The conferees told the Secretary of Defense to have ready by Feb. 1, 1995, a report outlining the actions DOD plans to take to address those concerns.

Total funding for the next largest recipient and disburser of federal research funds—the National Institutes of Health—also increased, up 4% to $11.3 billion, including $20 million for the construction of extramural research facilities. Funding for the institutes alone is also up 3% to $10.3 billion, as is funding for the AIDS research research conducted by all of the institutes, which totals $1.3 billion.

Funding for the National Institute of General Medical Sciences (NIGMS), which supports the majority of NIH's chemically related research, is up 3% to $902 million. NIGMS also is getting an additional $3.4 million from the Office of the Director for its minority access to research careers and minority biomedical research support program.

Although the NIH budget is up, Rep. John E. Porter (R.-Ill.), ranking minority member of the Appropriations Subcommittee on Labor, Health & Human Services, Education, and Related Agencies, is concerned that NIH's 4% increase isn't even enough to keep up with inflation. "NIH is a national treasure," Porter told fellow members, but "at this rate, we are going to lose new researchers and miss unprecedented opportunities to improve our health." Expressing similar concern in the Senate, Mark Hatfield of Oregon, ranking minority member of the full Appropriations Committee, says he will press next year for enactment of a new health research fund. Such a fund, financed by a 1% surcharge on private insurance premiums, would increase support for NIH by about 50% or $5 billion annually and would, moreover, provide a predictable, stable source of support.

Congress, for the most part, does not insert academic or any other kind of earmarks into NIH's budget. Conferees may, for example, "strongly encourage" the National Cancer Institute to expand its level of support for both diethylstilbestrol research and education efforts, but that's about as far as it goes.

The National Science Foundation is one of two bright spots in the otherwise dreary federal research budget. Its overall budget is up 11% to $3.4 billion, with funding for research and related activities up 13% to $2.2 billion. And Congress provided it with enough money to make a start on refurbishing the academic research infrastructure with a $250 million appropriation, plus $126 million for purchases of major research equipment. All of NSF's funds are disbursed on the basis of peer review of grant proposals, and Congress made no move to change or constrain that practice.

However, that can't be said of the other programs funded under H.R. 4624, the fiscal 1995 appropriations bill for the Departments of Veterans Affairs, Housing & Urban Development, and sundry independent agencies. When the bill left the House, it contained no earmarks. The Senate approved $135 million worth of earmarks. When the bill emerged from the conference, it contained a total of $290 million for earmarked projects, including more than $100 million worth of academic earmarks. These academic earmarks include 41 projects totaling $68.2 million funded by HUD, 32 projects worth $32 million funded by the VA, $3 million from the National Aeronautics & Space Administration for a regional ecosystem computer-based modeling project at Ohio State University, and $500,000 from the Federal Emergency Management Agency for the University of Nevada, Reno, earthquake engineering center.

Efforts to cancel out the earmarks were unsuccessful in both the House and the Senate. The Senate even defeated an amendment that would merely have required the conference committee to spell out in its report whether earmarked expenditures were contained in the House bill or committee report, the Senate bill or committee report, or were added by the conferees. However, earmarks or not, the bill did increase funding for NASA's science, aeronautics, and technology programs by 2% to $5.9 billion. Funds for the Environmental Protection Agency's extramural research program are up 3% to $350 million.

With its budget set at $790 million, a 52% increase over its fiscal 1994 funding, the Department of Commerce's National Institute of Standards & Technology is the brightest spot in the fiscal 1995 research picture. Funding for NIST's core research programs is set at $265 million, an increase of 17% over fiscal-year 1994. Of that amount, $7 million is for work on environmental technologies and $5 million is for the international trade and standards program.

However, the real growth at NIST is occurring in its outreach programs. Congress provided $431 million—an increase of more than 100%—for the joint NIST-industry Advanced Technology Program and $90.6 million for the Manufacturing Extension Program, a threefold increase. Meanwhile, funding for the National Oceanic & Atmospheric Administration's research programs is also up, but by just 14% to $259 million.

The Department of Agriculture's research budget is up just 1% at $1.4 billion, but the Department of Energy is the only agency whose research budget actually falls in fiscal 1995. Once primarily a research agency, DOE is now spending almost 50% of its $11.8 billion budget on environmental restoration and waste management. Funding for its energy R&D programs is down 9% to $5.2 billion, and funding for its core weapons R&D activities is down 32% to $777 million. ☐

Congress freezes overall funds for R&D agencies in '95

$ Millions	1994	1995		% difference, appropriation-request	% change 1994–95
		Administration request	Congressional appropriation		
Defense	$34,934	$36,225	$35,870	–1%	3%
Air Force	12,259	12,349	12,203	–1	0
Defense agencies	8,710	9,417	9,099	–3	4
Navy	8,301	8,935	8,796	–2	6
Army	5,421	5,260	5,521	5	2
Other	243	264	251	–5	3
NASA	15,621	14,241	14,377	1	–8
Science, aeronautics & technology[a]	5,788	5,901	5,891	0	2
Human space flight[a]	6,672	5,720	5,574	–3	–16
Mission support[a]	2,653	2,663	2,555	–4	–4
Energy	12,749	12,198	11,822	–3	–7
Environmental restoration & waste management	5,899	5,938	5,837	–2	–1
Energy R&D	5,713	5,464	5,208	–5	–9
General science & research	1,615	1,074	984	–8	–39
Superconducting Super Collider termination costs[a]	640	143	0	na	na
Supporting research & technical analyses	976	956	952	0	–2
Materials sciences[a]	277	274	276	1	0
Chemical sciences[a]	169	162	164	1	–3
Waste R&D	687	703	703	0	2
Conservation	392	601	490	–18	25
Biological & environmental research	416	435	445	2	7
Fossil	431	451	443	–2	3
Solar & renewables	347	410	388	–5	12
Fusion	348	373	373	0	7
Nuclear	341	312	293	–6	–14
Environment, safety & health	160	149	137	–8	–14
Weapons R&D—core	1,137	796	777	–2	–32
NIH	10,938	11,472	11,334	–1	4
National institutes	10,001	10,434	10,310	–1	3
General Medical Sciences[a]	876	908	902	–1	3
National Center for Research Resources	332	351	360	3	8
National Center for Human Genome Research	127	152	153	1	20
Other	478	535	511	–4	7
NSF	3,019	3,199	3,360	5	11
Research & related activities	1,994	2,348	2,245	–4	13
Education & human resources	570	586	606	3	6
Major research equipment	—[b]	70	126	80	na
Academic research infrastructure	105	55	250	355	138
Other	350	140	133	–5	–62
USDA	1,416	1,347	1,436	7	1
Agricultural Research Service	728	725	740	2	2
Cooperative State Research Service	495	419	496	8	0
Forest research	193	203	200	–1	4
Commerce	747	1,173	1,049	–11	40
National Institute of Standards & Technology	520	935	790	–16	52
Oceanic & atmospheric research	227	238	259	9	14
EPA extramural R&D	339	364	350	–4	3
TOTAL	$79,763	$80,219	$79,598	–1%	0%

[a] Funds included in preceding total. [b] Data not available. **na** = Not applicable.
Source: Appropriations Committees' conference reports

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CHEMICAL & ENGINEERING NEWS

C&EN

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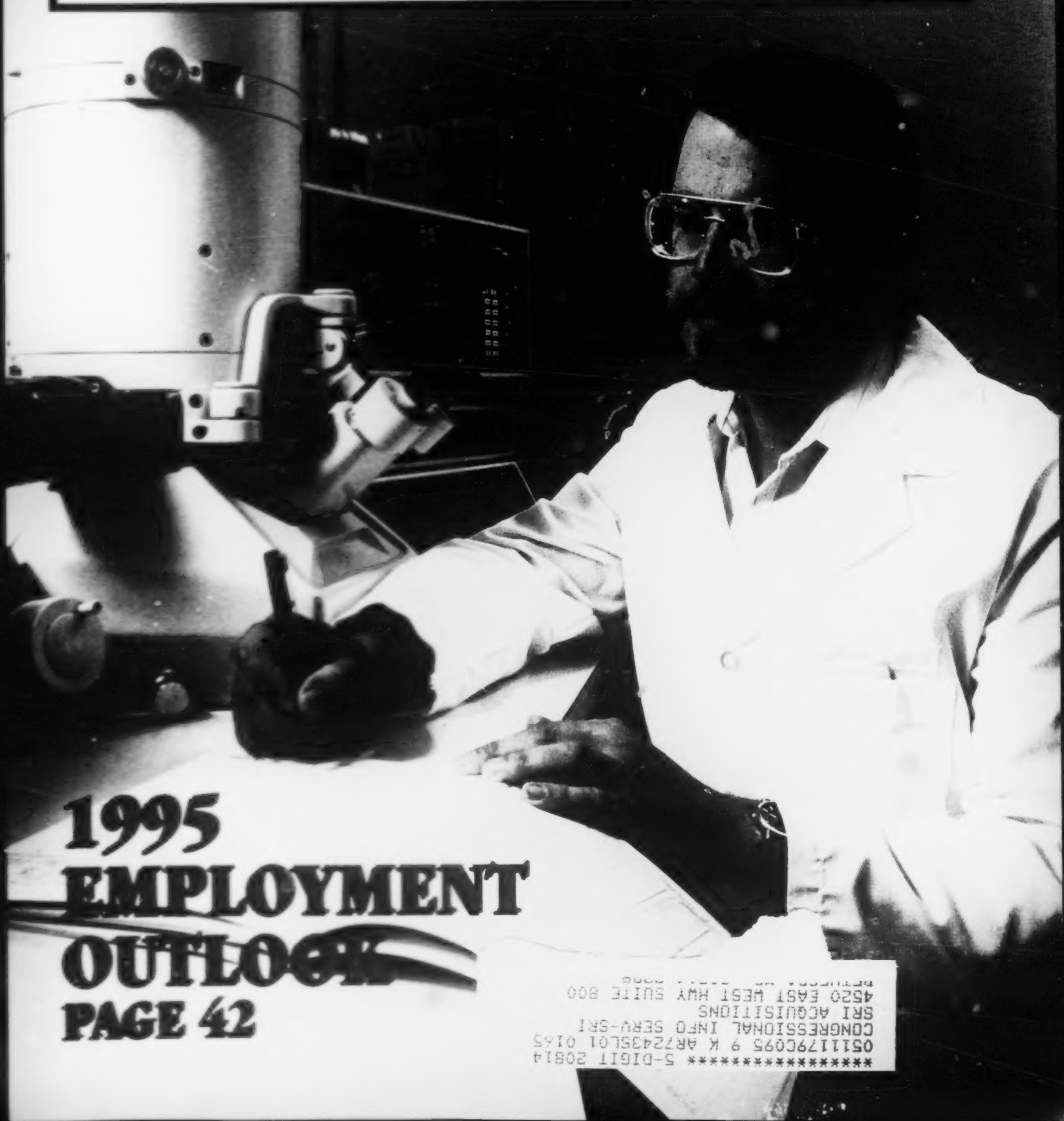

1995 EMPLOYMENT OUTLOOK

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CHEMICAL & ENGINEERING NEWS

C&EN

OCTOBER 24, 1994

NEWS OF THE WEEK

- New data suggest that nitrogen radicals from the exhaust of supersonic aircraft may not pose as serious a risk to the stratospheric ozone layer as once thought. Page 6
- Heavy rains and floods in the Houston area last week forced at least two chemical plants to shut down and halted chemical shipments in the Houston Ship Channel. Page 7
- Monsanto draws fire on several counts as controversy continues to swirl around its recombinant bovine growth hormone. Page 7
- Some 14 million Americans are routinely exposed to herbicides in their drinking water, according to a new environmental report. Page 8
- The Office of Naval Research and Stanford University have settled a more than four-year-old dispute over payment and billing of indirect research costs. Page 9
- A new program launched by NSF is aimed at raising the quantity and quality of bachelor degree graduates in science, math, and engineering at schools serving blacks, Hispanics, and Native Americans. Page 9

COVER: Dow Chemical senior research technologist records operating parameters of transmission electron microscope. Photo by Jeffrey R. Glenn

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BUSINESS

Recovering economies and increased demand for production of gasoline oxygenates are leading to tighter supplies of methanol as its transformation to commodity status appears complete. **Page 13**

Most states had increases in personal income from the chemical industry in 1993, according to the Commerce Department. **Page 16**

GOVERNMENT

Upcoming elections are not likely to change the science-related leadership in Congress, although some changes for science and technology subcommittees are in store. **Page 18**

Bill authorizing compensation to veterans disabled by Gulf War syndrome has been approved by Congress, as cause of illness continues to be sought. **Page 22**

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Producers of pharmaceutical ingredients and intermediates expand chemical capabilities, strengthen basic technologies to adapt to changing demands within the drug industry. **Page 24**

A new computer workstation packs the power of a supercomputer into a desktop machine at a fraction of the cost. **Page 34**

A plasmid DNA vaccine protects mice against infection by the parasite that causes malaria and raises hope that an effective malaria vaccine is feasible. **Page 36**

EDUCATION

Courses that address ethical research practices in chemistry and related sciences are beginning to be offered by some university chemistry departments. **Page 38**

EMPLOYMENT OUTLOOK

C&EN's annual look at the job market finds it opening up a bit for new chemistry graduates, but job seekers are advised to consider a broad range of options. Page 42

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1155—16th St., N.W., Washington, D.C. 20036
Editor: Michael Heylin (202) 872-4501
Managing Editor: Madeleine Jacobs
Assistant Managing Editors: Rudy M. Baum, Ernest L. Carpenter, Janice R. Long, Rebecca L. Rawls, William J. Storck
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News Bureaus: Northeast: (908) 906-8300 Ann M. Thayer (Head), Elisabeth Kirschner (Assistant Editor), George Peaff (Assistant Editor), Rachel Eskenazi (Administrative Assistant). Houston: (713) 558-2912 Susan J. Ainsworth (Head). Washington: (202) 872-4495 David J. Hanson (Head), West Coast: (206) 517-5034 Deborah L. Illman (Associate Editor). London: (01) 44 81 870-6884 Patricia Layman (Senior Editor), (01) 44 256-811052 Michael Freemantle (Senior Editor)
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LETTERS

Laboratory-based instruction

The article titled "Chemistry Curriculum Reform Focuses on Content, Technology, and Pedagogy" (C&EN, Aug. 29, page 35) is a landmark summary of research reports related to laboratory instruction in beginning-level college chemistry and also related to the nature of chemical education research. Unfortunately, the papers on these two subjects, presented at the 13th Biennial Conference on Chemical Education, as reported in the article, confuse the need to change the content of laboratory instruction with the need to reform the pedagogical approach to this instruction.

One presentation given at the conference did differentiate between these two needs; however, it was not included in the summary article. The presentation reported on the first phase of an extensive study conducted by a team of researchers at Temple University (F. Sutman, J. Schmuckler, A. Hilosky, and S. Rubin). In the study, instruction in 26 chemistry laboratory sessions in the U.S. and in Germany was analyzed by using an instrument designed and validated to describe pedagogical approaches.

The results of the study are most revealing because they indicate that although every laboratory instructor in the U.S. sample espoused primary significance to laboratory instruction, in no instance did assessment of student learning procedures reflect learning outcomes from the laboratory experiences. In the German population, however, assessment of learning was totally based on the laboratory component of the chemistry course.

In the U.S. sample, laboratory instructors devoted almost all of their teaching effort to listening to and answering students' questions about laboratory procedures. This left little or no time to devote to faculty-student interaction for explaining what students observed or to other higher order concerns related to chemical theory. This practice dominated the laboratory time even though students were expected to read and to understand the procedural steps for the laboratory experiment prior to entering the laboratory, and even though the commercially available printed directions included higher order questions, supposedly to be addressed during the postlaboratory instructional period. These questions were never addressed.

Even in the experimental chemistry courses (in the U.S.), developed through support from the National Science Foundation, the laboratory experiences were totally separated and unrelated to the lecture. In no instance did instructors develop lecture recitation as an outgrowth of the laboratory experience.

The laboratory and course instructors, whose instruction was analyzed, had only two professional contacts with pedagogical concerns: a subscription to the *Journal of Chemical Education* and infrequently reading a related article in C&EN. During the followup interviews to the analysis of laboratory instruction, they described how they had changed their pedagogical approach, when in fact all they had done was find new content to be taught in the same way.

Many other significant findings have evolved from this comprehensive research. Those who are interested in these findings are invited to contact the researchers or to look for future reports of the research in the *Journal of Chemical Education*.

Francis X. Sutman
Temple University and
Rowan College of New Jersey
Glassboro

Lewis Chiral?

The article on chiral drugs (C&EN, Sep. 19, page 38) includes the quote from Lewis Carroll, "Perhaps looking-glass milk isn't good to drink." I have always found myself using the same quote when beginning to lecture on stereochemistry. "Through the Looking Glass" was published in 1871, quite a few years after Pasteur had separated his tartrate crystals in 1848, but two years before van't Hoff's and LeBel's works dealing with the tetrahedral nature of carbon. Is it known if Carroll understood the chiral nature of Alice's question or was it just an offhand remark?

Eugene J. McDevitt
Siena College
Loudonville, N.Y.

Correction

- Oct. 17, page 4: The late physical organic chemist Saul Winstein, not Weinstein, was a professor at University of California, Los Angeles, not Harvard University.

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Methanol's Transformation To Commodity Status Stretches Supply

■ ***Recovering economies, increased demand for methanol in production of gasoline oxygenates lead to higher prices***

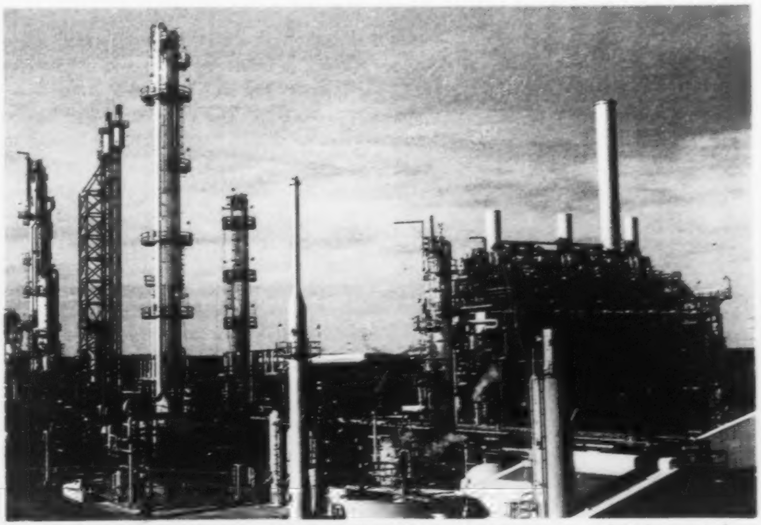
George Peaff,
C&EN Northeast News Bureau

Methanol is undergoing a renaissance. Beginning in the U.S. in the fourth quarter of 1993, methanol has seen a transformation from a low-growth, low-priced, overly abundant commodity chemical into a high-demand, undersupplied, cost-price driven product. As the economic recovery has spread to the rest of the world, methanol demand has dramatically increased. This meteoric rise has been further sparked in the U.S. by increased use of methanol as an ingredient in gasoline oxygenates required by the federal government.

Increased demand has led to the consolidation of producers, a scramble to reopen existing capacity, addition of capacity via product conversion, and plans for various future capacity expansions.

Methanol fits alongside the other long-standing, major organic commodity chemicals—ethylbenzene, ethylene, ethylene dichloride, formaldehyde, propylene, styrene, terephthalic acid, and vinyl chloride. Methanol also serves both as a building block for many other chemicals—formaldehyde, acetic acid, and terephthalic acid—and as a solvent for many industrial uses.

Bruce Aitken, commercial vice president for Methanex, Vancouver, British Columbia, says the run-up in methanol pricing was first "based on the traditional uses of methanol such as acetic acid." Methanol prices jumped higher in August, he adds, when demand for use in methyl *tert*-butyl ether (MTBE) increased to meet U.S. wintertime gasoline requirements and the Environmental Protection Agency's new oxygenated fuel requirements slated to go into effect Jan. 1, 1995.



Terra Industries entered the methanol market in June with the opening of its integrated methanol/ammonia facility in Woodward, Okla.

From a 50-cent-per-gal range in fourth-quarter 1993, barge price for methanol reached $1.30 per gal by mid-October, producer and industry sources say. "If you look at year to year, between 1993 and 1994, there's another 2.87 billion lb of methanol going into MTBE," Aitken states. He projects an additional 2.87 billion lb going into MTBE for 1994–95.

Aitken sees methanol being in short supply for the rest of 1994, and he believes the market will bid up the value of a commodity in scarce supply. Both methanol and MTBE display classic commodity characteristics.

A product gains commodity status when its use becomes an everyday necessity. Supply and demand may change over the course of time depending on the ups and downs of the economic cycle, but a central demand for a commodity product ensures its producer a continuous market for that commodity product.

Although a commodity product tends to garner lower prices because so much of it is produced, its bulk volume and necessity status perpetuate a continuous market. However, a weaker or stronger economy, introduction of new uses, emerging replacements, or a catastrophe may all have an impact on supply and demand.

About 27% of methanol produced in 1993 was used in MTBE. Methanol also serves as a key ingredient in production of formaldehyde, acetic acid, chloromethanes, methyl chloride, methylene chloride, chloroform, methyl methacrylate, dimethyl terephthalate, methylamines, acetic anhydride, glycol methyl esters, and numerous phosphorus derivatives.

MTBE's primary use is for blending into gasoline as either a replacement for lead-based octane enhancers or as an oxygenate to meet the cleaner burning gasoline standards set down by EPA under the Clean Air Act.

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In 1993, MTBE ranked ninth in terms of production at 24.1 billion lb, a 121% rise over 1992 when it was the 19th-ranked chemical in the U.S. according to C&EN's ranking of the Top 50 chemicals (C&EN, July 4, page 31). Methanol in 1993 was ranked 21st at 10.5 billion lb, a 30% rise in production over 1992 when 8.08 billion lb was produced. About 2.84 billion lb of U.S.-produced methanol went into the making of MTBE in 1993.

Global methanol supplies could be tight in 1995-96

Billion lb	1993[a]	1994[b]	1995[b]	1996[b]	1997[b]
Capacity	52.0	54.5	56.8	58.6	63.5
Demand	45.6	49.4	53.4	55.9	58.2
% utilization	88	91	94	95	92

a Estimate. b Forecast. **Source:** Crocco & Associates

According to Fred Peterson at Probe Economics, a consulting firm based in Millwood, N.Y., U.S. demand for MTBE was 19.9 billion lb in 1993, which would require about 7.22 billion lb of methanol to produce. However, since only 2.84 billion lb of the methanol produced in the U.S. went toward MTBE production, another 4.38 billion lb was imported for use in the U.S. to produce MTBE in 1993.

Peterson pegs U.S. MTBE demand by 2000 at around 67 billion lb. To meet that demand, 24.2 billion lb of methanol would be required. If EPA's 30% renewable oxygenate mandate survives, MTBE demand would be 46.9 billion lb, consuming 16.9 billion lb of methanol. A court challenge to EPA's ethanol mandate filed by several organizations representing the petroleum and methanol industries likely will be heard in late January 1995. Currently, ethanol is the only renewable oxygenate available to meet required demand.

Global demand for methanol will likely grow 6.2% per year through 1997, with methanol use in MTBE representing about half of that growth, according to a report by Crocco & Associates, a Houston-based consulting firm specializing in methanol.

Crocco estimates that worldwide methanol demand in 1993 reached 45.6 billion lb, with capacity at 52 billion lb and utilization at 88%. Forecasts predict demand to reach 49.4 billion lb for 1994, with capacity at 54.5 billion lb and a utilization rate of 91%. Currently, there are 33 methanol producers. By 1997, demand could reach 58 billion lb, with capacity reaching 63.5 billion lb and utilization at 92%, taking into account existing projects for new capacity and capacity expansions.

But in 1995 and 1996, Crocco forecasts capacity utilization could reach 94% and 95%, respectively, making methanol supplies tight and current pricing increases sustainable. Producers are unlikely to invest in large expansions despite greater demand, however, because they still remember both the low prices for methanol in the 1980s and early 1990s and the utilization rates ranging between 74 and 81%.

And because many existing plants are old, scattered shutdowns will also tighten supplies. For example, in late September Lyondell Petrochemical was forced to shut down its Channelview, Tex., methanol operation because of problems in one of the plant's synthesis gas units. The plant produces 4.2 million lb of methanol per day for use in MTBE. Production resumed on Oct. 6.

To further complicate the current tight supply, an explosion on Oct. 12 at Enron's Pasadena, Tex., methanol plant idled 2.72 million lb of daily production. Only minor injuries resulted, but production at that plant will remain shut down indefinitely as the company investigates the cause and resultant damage of the explosion. Methanex markets 40% of the methanol produced at the plant, with Enron utilizing 50% of the methanol at its neighboring MTBE facility.

Industry compensation for lost production as a result of plant shutdowns has been forthcoming, however. Terra Industries of Sioux City, Iowa, recently switched over part of one ammonia production plant to methanol production. Mike Drissell, Terra's manager of nitrogen products, explains that methanol producers are hesitant to spend $100 million to $150 million to add methanol capacity until the many side issues of fuel oxygenates are resolved. He includes among these issues the use of methanol and ethanol as straight fuels and other forms of non-gasoline-utilizing transportation, such as electric vehicles.

However, Terra looks favorably at methanol's prospects. "We think it is a business that has good long-term growth because the basic economy is that much stronger," says Drissell. "If you took MTBE out of the equation, obviously you would have an effect, but overall, the business is just that much better than it was four to five years ago."

The anticipated growth in the market for methanol has led to consolidations of existing capacities, the startup of new capacity, and the entry of new companies into the business.

Terra, also a large producer and marketer of nitrogen-based fertilizers, entered the methanol business after converting 800,000 lb of its 3 million-lb-per-day ammonia plant in Woodward, Okla., to methanol production. The company says the $15.5 million methanol plant will have an annual capacity of 269 million lb.

Also, as part of its pending acquisition of Agricultural Minerals & Chemicals (AMC), a nitrogen fertilizer producer in Tulsa (C&EN, Aug. 15, page 6), Terra will receive Beaumont Methanol, formerly a DuPont facility. Beaumont, with a 1.85 billion-lb-per-year methanol capacity, was purchased by AMC and a minority partner, Transammonia, a French trading group.

Methanex became the world's largest marketer of methanol after acquiring Nova Corp.'s methanol plants in early 1994. In 1993, Methanex produced 4.65 billion lb in its five plants located in Canada, Chile, and New Zealand. It also marketed an additional 2.09 billion lb for other producers.

Methanex's Aitken says capacity will reach 7.72 billion lb in 1994, including the addition of Nova's existing capacity and partial contributions from two expansions. Methanex is expanding New Zealand capacity by 1.54 billion lb and has entered a 70-30 partnership with Cytec for 1.21 billion lb of methanol to be produced at Cytec's converted ammonia facility in Avondale, La. Methanol marketed for others will reach 3.31 billion lb in 1994, says Aitken. In 1995, Methanex's annual capacity is expected to reach 10 billion lb.

Saudi Basic Industries Corp. (SABIC), the Saudi Arabian industrial conglomerate, is the next largest methanol producer, with annual capacity of about 4.63 billion lb. Saudi Methanol, a 50-50 partnership between SABIC and a Japanese consortium led by Mitsubishi Gas Chemical, has a 2.65 billion lb annual capacity. National Methanol, a 50-50 partnership between SABIC and CTE Petrochemicals, which itself is a 50-50 joint venture between Hoechst Celanese and Panhandle Eastern, has annual methanol capacity of 1.98 billion lb. As of Jan. 1, SABIC's marketing subsidiary assumed 100% marketing responsibility for National Methanol's production. National Methanol also produces about 1.54 billion lb of MTBE annually.

Gulf Petrochemical Industries—a partnership between Saudi Arabia, Kuwait, and Bahrain—operates an 882 million-lb-annual-capacity methanol plant in Bahrain, with SABIC Marketing holding the selling responsibility for that output. During the year, Saudi European Petrochemical, also part of the SABIC conglomerate, upped its MTBE capacity to 2.65 billion lb from 1.1 billion lb.

When Hoechst Celanese restarts its Clear Lake, Tex., 1.32 billion-lb methanol plant—for which it is still seeking a partner—it will become the third largest methanol producer worldwide. Hoechst Celanese already operates a 1.1 billion-lb plant in Bishop, Tex., and owns 46% of Edmonton Methanol, a 1.65 billion-lb plant. Celanese Canada, which is 56% owned by Hoechst Celanese, holds the other 54% interest in Edmonton Methanol, which for the most part serves the merchant market in Canada, the U.S., and the Pacific Rim. However, Hoechst Celanese has placed its stake in Edmonton Methanol up for sale.

Hoechst Celanese, one of the largest producers of formaldehyde and acetic acid, uses over 1.5 billion lb of methanol captively in its production. The remaining methanol is sold on the merchant market.

Statoil, Norway's state-owned oil company, expects to open a 1.9 billion-lb-per-year plant in Tjeldbergodden, Norway, by late 1996. Another three projects are just in the planning stage, including a 1.6 billion-lb-per-year plant in Theodore, Ala., proposed by a partnership involving Methanol One and Degussa; a 1.45 billion-lb plant in Bontang, Indonesia, to be owned by Kaltin; and a 1.45 billion-lb plant on Kharg Island, Iran, which will be owned by Iran's National Petrochemical Co.

As summed up by Aitken, while the world may currently be short one or two methanol plants, with the addition of five or six, overcapacity could return. ☐

Alpha Olefins Answers

Eduardo J. Baralt, Ph.D.

Q. I am interested in producing alkyl silanes. What can you tell me about this chemistry?

A. The direct addition of silanes to alpha olefins is also known as hydrosilation of alpha olefins. It is catalyzed by peroxides, ultraviolet light or transition metal compounds. In most commercial processes, a silane such as Cl_3SiH reacts with an alpha olefin in the presence of a catalyst (chloroplatinic acid, H_2PtCl_6, molar concentration $\geq 1 \times 10^{-8}$) to make an alkylchlorosilane.

$$CH_2{=}CHC_{16}H_{33} + Cl_3SiH \xrightarrow[60-120^\circ C]{H_2PtCl_6} Cl_3SiCH_2CH_2C_{16}H_{33}$$

$$\Delta H_{reaction} = -15 \text{ kcal/mole}$$

Other metals can catalyze this reaction, but chloroplatinic acid (CPA) is the preferred catalyst because of its high activity and low catalyst concentrations.

Olefin Order of Reactivity:
Alpha >> vinylidene > trisubstituted ≈ internal olefins

Side Reactions: The most common side reaction is the isomerization of alpha olefins to internal olefins. Low reaction temperatures (60 - 80°C) reduce isomerization.

$$CH_2{=}CHC_{16}H_{33} \xrightarrow{\text{CPA, Silane, } 60-120^\circ C} CH_3CH = CHC_{15}H_{31}$$

The alkyltrichlorosilane is frequently reacted with an alcohol to make an alkyltrialkoxysilane:

$$Cl_3SiCH_2CH_2C_{16}H_{33} + 3\,ROH \rightarrow (RO)_3SiCH_2CH_2C_{16}H_{33} + 3HCl$$

Methanol, ethanol and t-butanol are the preferred alcohols since they can be readily removed when coating a surface:

$$(RO)_3SiC_{18}H_{37} + 3\,[Al\text{-}O\text{-}H]_{(surface)} \rightarrow 3\,[Al\text{-}O\text{-}]_{(surface)}\text{-}SiC_{18}H_{37} + 3ROH$$

If you have any questions about alpha olefins, please contact our Houston office.

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Chemical payrolls increased slightly last year

The U.S. chemical industry is generally not labor intensive. As a result, while the industry contributes about 1.9% of the U.S. gross domestic product, the salaries, wages, and dividends the chemical industry paid out in 1993—totaling almost $61.4 billion—made up just 1.1% of the total $5.26 trillion in personal income in the U.S. last year, according to the Department of Commerce.

The restructuring and downsizing in the chemical industry have taken a toll on personal income growth. The $61.4 billion paid out in 1993 for chemicals and allied products was 2.6% higher than the previous year. Growth in 1992 was almost three times higher at 7.4%. And growth for total personal income was 4.4% in 1993, down from 6.1% the year before.

Chemicals and allied products is well down on the list of industries in terms of contribution to total personal income. It is easily dwarfed by retail trade at $368 billion and, among the service industries, by health services at about $343 billion. However, among manufacturing industries in 1993, chemicals and allied products came in third following machinery and computer equipment, at $84.1 billion, and electronic equipment, excluding computers, at $63.3 billion.

Among the 50 states, New Jersey and Texas rank first and second in terms of personal income from chemicals, between them accounting for 22% of chemicals-derived income nationwide.

With New Jersey's large number of corporate headquarters providing higher paying jobs, and its concentration of the pharmaceutical industry, personal income from chemicals in the state last year was $6.86 billion, up a slight 0.5% from the previous year and accounting for 3.3% of total personal income for the state's residents.

New Jersey was followed relatively closely in total dollars by Texas at $6.43 billion. This accounted for 1.9% of total state personal income in Texas. Personal income from chemicals was up 4.5% in 1993 from the previous year.

Texas has perhaps the largest number of industrial chemical plants in the U.S. Although the Commerce Department provides no analysis of the data, the larger than average increase in personal income in Texas is perhaps a result of the larger percentage of production workers in the state—a segment of employment that has grown while white-collar jobs have declined.

Number three, Illinois, trailed the first two states by a wide margin with personal income from chemicals at $4.13 billion, up 4.8% from the previous year.

Although most of the states were in the less than 1 to 3% range in terms of chemical contribution to total state personal income, there is one standout. Delaware, perhaps not surprisingly considering the companies located there, had about $1.84 billion in personal income contributed by the chemical industry. This amount is 12% of the state's personal income and it makes chemicals the largest contributor. However, because of the reductions in employment at major Delaware chemical producers such as Hercules, ICI, and of course, DuPont, chemicals-derived personal income has declined. The dollar figure in 1993 was down 4.9% from 1992, which itself had been down 3.9% from 1991.

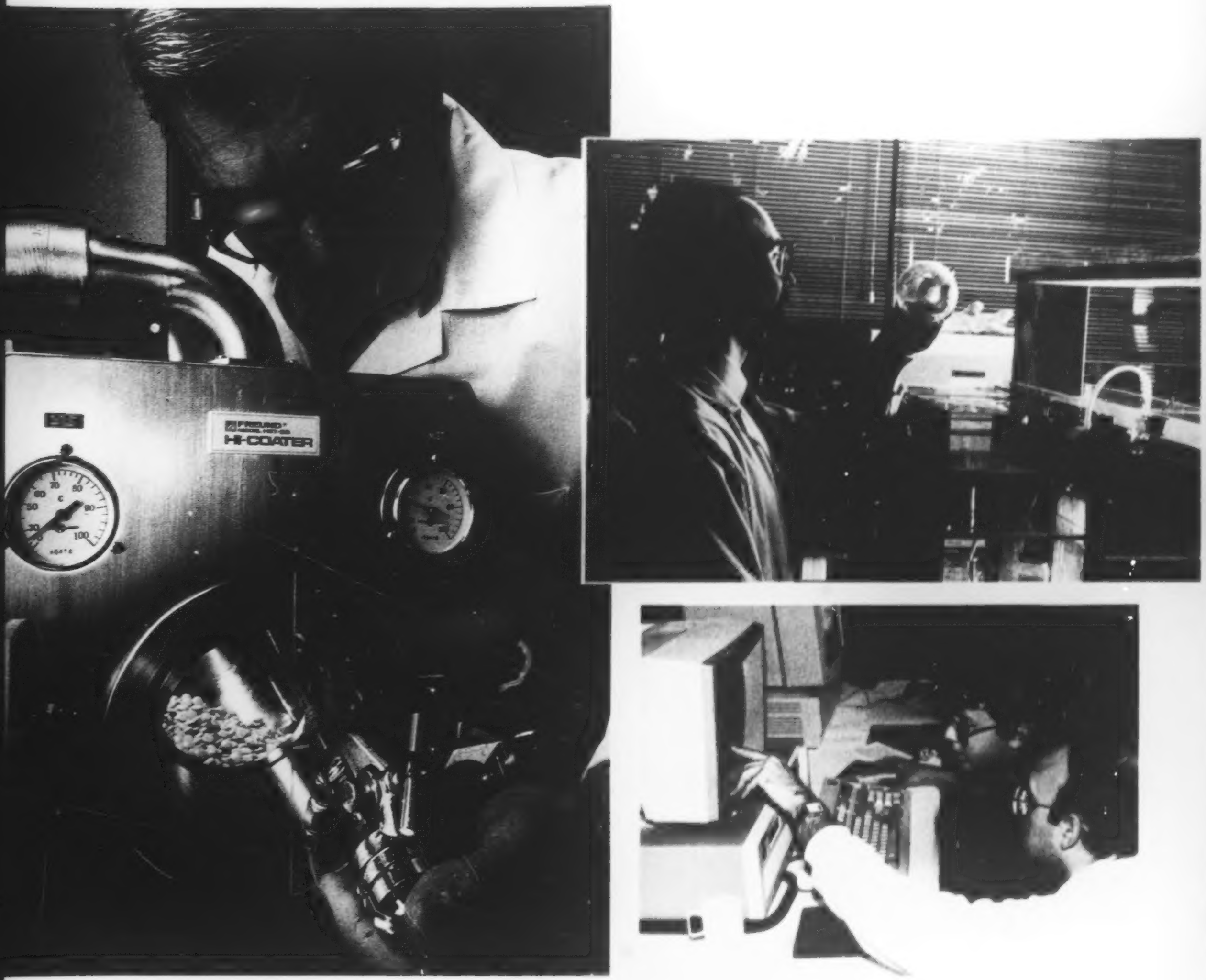
Besides Delaware, four other states had declines in personal income last year. Virginia was down 8.1% to $1.15 billion, Florida dropped 2.9% to $957 million, New York was off 2.6% to $3.44 billion, and Massachusetts fell 1.3% to $891 million.

William Storck

Most states had increases in chemical industry personal income

$ Millions	Personal income derived from chemicals	Percent change from 1992	Income from chemicals as % of state personal income
Alabama	$ 602	2.2%	0.8%
Alaska	28	7.7	0.2
Arizona	246	6.5	0.3
Arkansas	229	4.1	0.6
California	3,515	4.8	0.5
Colorado	554	2.2	0.7
Connecticut	1,349	1.7	1.5
Delaware	1,835	–4.9	12.1
Florida	957	–2.9	0.3
Georgia	847	5.6	0.6
Hawaii	19	0	0.1
Idaho	198	4.8	1.0
Illinois	4,134	4.8	1.6
Indiana	2,048	6.0	1.9
Iowa	299	5.3	0.6
Kansas	297	1.4	0.6
Kentucky	720	3.7	1.1
Louisiana	2,053	3.5	2.9
Maine	47	9.3	0.2
Maryland	671	5.0	0.6
Massachusetts	891	–1.3	0.6
Michigan	2,500	3.4	1.3
Minnesota	562	5.0	0.6
Mississippi	311	5.1	0.8
Missouri	1,548	4.1	1.5
Montana	$ 24	9.1%	0.2%
Nebraska	121	0.8	0.4
Nevada	38	0	0.1
New Hampshire	249	6.0	1.0
New Jersey	6,861	0.5	3.3
New Mexico	47	6.8	0.2
New York	3,436	–2.6	0.8
North Carolina	2,391	4.0	1.8
North Dakota	5	0	0.1
Ohio	4,123	6.5	1.9
Oklahoma	159	6.0	0.3
Oregon	114	7.5	0.2
Pennsylvania	3,790	1.8	1.5
Rhode Island	135	9.8	0.6
South Carolina	1,984	3.9	3.2
South Dakota	9	0	0.1
Tennessee	1,779	0.9	1.9
Texas	6,425	4.5	1.9
Utah	145	21.8	0.5
Vermont	26	4.0	0.2
Virginia	1,154	–8.1	0.8
Washington	326	12.0	0.3
West Virginia	906	0.1	3.1
Wisconsin	594	8.0	0.6
Wyoming	53	12.8	0.6
TOTAL	**$61,354**	**2.6%**	**1.1%**

Note: Personal income is made up of salaries, wages, and other labor income, dividends and interest, rental income, and government transfer payments such as social security, unemployment, and veterans benefits. **Source:** Department of Commerce



DEMAND

Rebecca L. Rawls, C&EN Washington

It's not exactly a groundswell. In fact, one observer says it's not even a light at the end of the tunnel, because it's not that big yet. It's more like a bit of light beginning to show through the cracks in a wall. But however it's phrased, the sentiment among many recruiters, chemistry department chairmen, college placement directors, and other close observers of chemical employment is that there will be more jobs for chemists graduating in 1995 than there were in 1994 or 1993.

However, the 1995 recruiting season, which gets under way this month, will still be a challenging one for job seekers. The recovery that observers are beginning to predict is from a very poor base; 1994, by many standards, was one of the worst years in two decades to be looking for a job in chemistry. And, as always, some degree levels and some fields of specialization will be more promising than others.

At the bachelor's level, most observers contacted by C&EN are calling the employment market not too bad, not great, but with jobs enough to go around as long as students are resourceful and spread their nets widely. For Ph.D.s and those in postdoctoral positions, the market—though improving—is expected to stay very tight for at least another year. The already swollen postdoctoral pool is likely to get even larger in 1995, growing in part because many newly graduating Ph.D.s will not be finding the permanent jobs they want in industry or academia. The effect of a slight increase in jobs is

ACS starting salary survey confirms tight market for newly graduated chemists

The job market was tight for chemists who received their degrees last winter or spring. For both new bachelor's level chemists and Ph.D.s, job offers were scarce and unemployment was high when compared with historic trends. Perhaps partly for this reason, the fraction of 1994 graduates deciding to stay out of the job market for a few more years by going to graduate school or taking a postdoctoral position remained high.

That's the picture to be drawn from the early data in ACS's most recent annual survey of newly graduated chemists and chemical engineers, conducted over the summer. Responses have been particularly slow in coming this year, says statistician and senior research analyst Joan S. Burrelli of ACS's Office of Professional Services, who directs the survey. Data for chemistry graduates are based on about 2,200 responses, or roughly one fifth of the people who received degrees in chemistry in the U.S. between September 1993 and June 1994.

For chemists with new bachelor's level degrees, just over half—52%—were planning to be full-time students this fall, with another 9% planning part-time advanced study. That's down slightly from 1993 and 1992, when 54% and 55%, respectively, of B.S. graduates were headed for full-time advanced study. This year, 30% of the bachelor's level chemists had full-time employment by mid-summer, and three out of four of them considered their work to be in chemistry. That leaves 16% seeking employment, up from 14% in 1993 and 9% in 1992. The last time the survey found such high unemployment among recently graduated bachelor's level chemists was in 1985.

Some 60% of those entering the work force with bachelor's degrees went to work in industry, with the remainder divided more or less evenly among colleges and universities, high schools, hospital and independent laboratories, and everything else. In that respect, the new graduates followed the general pattern of recent years. Their median salary—the salary met or exceeded by 50% of the individuals in the group—was $25,000, up from a median of $24,000 a year earlier. However, the movement of starting salaries, particularly at the B.S. level, is always a bit jerky. When the median changes, it often does so by $1,000, and this year's jump is the first change in two years for this figure.

A closer look at where the industrial jobs were for new bachelor's level chemists reveals some of the distinctive character of the 1994 job market. Of those going to work in industry, 29% found their jobs at pharmaceutical firms. The next largest group, with 21%, took nontraditional jobs for chemists—in industry, but not for manufacturing companies. Next came jobs with specialty chemical makers and with other types of manufacturers, which each provided 17% of the jobs found. Manufacturers of basic or agricultural chemicals and petroleum companies were essentially not hiring new B.S. chemistry graduates.

Almost half of B.S. chemistry graduates who went to work in industry found jobs at companies with fewer than 500 employees, and another 22% found work with companies with 500 to 2,499 employees. Only 15% went to big companies with 25,000 or more workers. Almost half of the inexperienced B.S. chemists who found work—48%—accepted the only job they were offered.

The job market for newly graduating Ph.D. chemists was, if anything, even tighter than that for B.S. graduates, according to the survey. By midsummer after their graduation, only 40% had found full-time employment. Essentially the same number—41%—had accepted postdoctoral fellowships, and another 17% were unemployed and looking for work. The rest were not seeking employment. Those numbers are almost the same as those for the previous year, when 41% had full-time employment, 41% had postdoctoral fellowships, and 16% were looking for work. It's small comfort, however, to say that 1994 wasn't any worse than 1993 for new Ph.D.s looking for work, since—until 1994 came along—1993 had been by most measures the worst year in more than a decade to be entering the job market with a Ph.D. in chemistry.

Unlike the bachelor's level, where 1994 salaries climbed a bit from their

dampened very considerably by the presence of that pool of postdocs, some of whom compete directly with new graduates for the positions whose numbers are just beginning to grow.

Still, the sentiment heard over and over from observers this fall is that there is some movement in the job market, and that movement is definitely in the right direction.

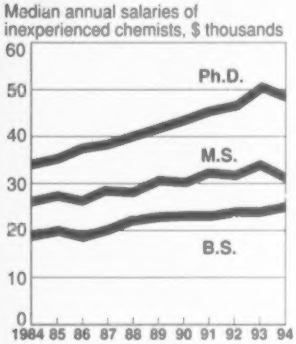
"Chemical companies, in particular, seem to be doing more hiring than they did last year," says Joel Shulman, manager of doctoral recruiting for Procter & Gamble. Dennis H. Guthrie, manager of university relations at Dow Chemical agrees. "I've spoken to a lot of my counterparts in the industry," Guthrie says, "and the hiring outlook for 1995 across the board in the chemical industry does indeed look like it's turning up." Both men are quick to point out, however, that hiring by chemical companies has been very low for the past two years, so that even though recruiting will be stronger for 1995 graduates, it will remain far below the levels of five to eight years ago.

Indeed, some close observers of industry recruiting estimate that the large chemical and diversified companies—those that might hire several dozen Ph.D. chemists in a single year—will be hiring about 30% more Ph.D. chemists in 1995 than they did in 1994. Five years ago, those same companies were hiring four times as many chemists as they did in 1994. So, although the percent change may look impressive, the numbers are still relatively small.

"We're seeing a little bit of activity," says Rebecca J. Simon, placement director for the school of chemical sciences at the University of Illinois, Urbana-Champaign, confirming the picture painted by corporate recruiters. "Some companies have come back to campus [on recruiting visits] that haven't been here for awhile. But instead of coming in for the major part of a week, like they used to, they are coming in for one day. I guess that's better than nothing."

At the bachelor's and master's levels, 1995 isn't shaping up to be an easy year to find a job. However, it looks to be much better than 1994 has been, when 16% of new B.S. chemists were still seeking employment at midsummer, according to preliminary data from the American Chemical Society's annual survey of new chemistry graduates. That's the highest level of unemployment among new B.S. chemists that the survey has

Starting salaries for Ph.D. chemists slip . . .

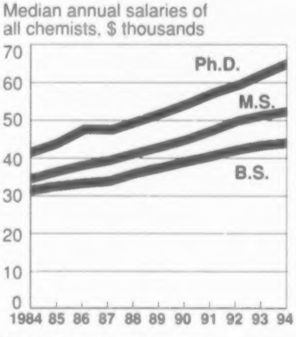


Note: Data as of the summer of each year.

1993 levels, the newest crop of Ph.D. chemists were accepting slightly lower pay than their counterparts in the previous year. The median salary dipped to $49,100 for 1994 graduates, a drop of about 3% from the $50,400 median of 1993. Men, who outnumbered women by about 2 to 1, had a median salary of $52,000, 30% higher than that for women. That difference largely disappears, however, when the type of employer is taken into account. For those taking jobs in private industry, the median salary for men—$55,000—was within 1% of the median for women. These are very small samples, however, with only nine women and 29 men reporting salary information for jobs in private industry.

Another 20 new Ph.D. chemists took jobs at colleges and universities, where the median starting salary this year was $31,750, a substantial 13% more than the median had been in 1993. Although these salaries are much lower than what industry is paying entry-level Ph.D.s, they are not, in many cases, the best paying entry-level jobs for chemists in academia. By and large, tenure-track positions at Ph.D.-granting universities require postdoctoral experience.

. . . as salaries for all chemists keep growing



Note: Data as of March of each year.
Source: ACS annual surveys

At the master's level, the survey found 44% of new graduates intended to continue full-time study this year, which is typical for recent years. About the same number—46%—had found full-time employment, and 10% were unemployed and looking for work. Although down from the 12% who were looking for work a year earlier, such double-digit unemployment is unusual for new graduates at this degree level, just as it is for B.S. and Ph.D. recipients. The median salary for inexperienced M.S.-degree holders fell to $30,000, down 12% from 1993, and back to the median amount new master's degree chemists were earning in 1990.

The College Placement Council (CPC) also collects data on starting salary offers made to newly graduating chemists. This year, it finds the median offer for new Ph.D. chemists to be $53,100, down $900 or 2% from last year's median. For B.S. chemists, this year's median of $27,500 is down $775 or 3% from last year's level. Because of differences in the way the two surveys are conducted, the CPC survey generally finds salaries a bit higher than the ACS survey does.

The complete ACS report, "Starting Salaries 1994," will be available later this year for $29.95 per copy from the Product Services Department, American Chemical Society, 1155—16th St., N.W., Washington, D.C. 20036. Questions or comments should be directed to Joan Burrelli at (202) 872-4433.

found since 1985. (For additional information from this survey, see box above.) "I would say [1995 will be] a competitive, but not outrageous, situation for the graduating B.S. chemist," says James D. Burke, manager of research recruiting and university relations at Rohm and Haas, summing up the view of many observers. "What the B.S. chemists do not have working against them is a big postdoctoral pool," he adds.

Recruiting at the Ph.D. level will be very selective this year, many observers say. "I think companies are looking very closely at what their needs are and trying to meet those, rather than having the ability to look for good people in a variety of areas, figuring that they can find a place for them," says Kenn E. Harding, chemistry professor and graduate adviser at Texas A&M University. "Recruiters are being very cautious," Simon agrees. "They are looking for somebody with specific skills, and they want people right now. When [a work unit within a company] finally gets a position to fill, they need a person in it immediately." That makes job hunting hard for Ph.D. candidates, she points out, who frequently interview as much as a year and a half before they expect to complete their degree requirements.

As has been true for the past several years, the favored fields for Ph.D. chemists this year seem to be analytical chemistry and synthetic organic chemistry, particularly those specializations within each field that are attractive to pharmaceutical companies. Drug companies have become the major employer of Ph.D. chemists who go to work in industry, claiming 39% of new chemistry Ph.D.s going directly into industry in both the 1993 and 1994 academic years, according to ACS's annual surveys. Prior to that, when chemical and diversified manufacturing companies were hiring more Ph.D. chemists, the pharmaceutical industry still hired a quarter to a third of each year's graduates who went directly into industrial jobs.

Pharmaceutical companies hire a significant number of chemistry postdocs, as well. In fact, several observers point out that although part of the reason for the growing number of chemistry Ph.D.s in postdoctoral positions is the poor job market for new graduates, another important reason is the preference many pharmaceutical companies have for hiring people with three or four years of postdoctoral experience when hiring for entry-level research positions. By contrast, when chemical companies hire postdocs or when universities do, they usually want people with two years of postdoctoral experience. Thus, the growing importance of the pharmaceutical industry as an employer of chemists is another reason for people to stay longer in postdoctoral positions.

These two forces have combined to swell the pool of chemistry postdocs to levels estimated by some observers as being as high as 4,000 to 4,300 people. That's the equivalent of two years' worth of Ph.D. graduates and may be twice the number of those who were in such positions a decade ago.

At the other end of the demand spectrum for Ph.D. chemists are the physical chemists, who, like their colleagues coming out of physics departments, face a very tight job market. Largely because of cutbacks in spending by the Department of Defense, jobs for physicists and physical chemists at both national laboratories and Defense Department contractors are very scarce. "Because defense industries are downsizing, the spectrum from physical chemistry all the way over into physics has become a fairly tight, if not bleak, area of employment," confirms Bruce Ganem, chemistry department chairman at Cornell University.

The difference in the employment prospects for different types of Ph.D. chemists is beginning to cause some strain at universities, says Robert J. Sibley, chemistry department chairman at Massachusetts Institute of Technology. "In chemistry departments, you have a span from biochemists and even some biotechnologists all the way over to physical chemists and people who might even be thought of as physicists. The biochemists are not having trouble getting jobs. They may not be getting the perfect job, but they are getting jobs. Whereas the physical chemists, especially the ones more and more into the physics side, are in really much deeper trouble. That's just the way the market is, but it makes problems in the department, because for some people the world is fine, and for other people it's not so fine."

More B.S. chemists, fewer Ph.D.s graduating

	Degrees awarded in chemistry[a]			Degrees awarded in chemical engineering[b]		
	Bachelor's	Master's	Ph.D.	Bachelor's	Master's	Ph.D.
1978	10,350	1,798	1,532	4,225	1,019	251
1979	10,451	1,716	1,532	4,977	951	237
1980	10,170	1,698	1,561	5,348	974	243
1981	10,453	1,609	1,613	5,831	1,020	250
1982	9,866	1,645	1,683	5,963	1,171	293
1983	10,043	1,569	1,759	7,021	1,317	333
1984	9,819	1,637	1,777	6,866	1,436	357
1985	9,679	1,621	1,806	6,442	1,489	418
1986	9,295	1,620	1,885	5,229	1,244	460
1987	8,848	1,636	1,936	4,435	1,078	533
1988	8,372	1,584	1,955	3,524	1,036	603
1989	8,125	1,710	1,970	2,891	919	574
1990	7,650	1,605	2,131	3,170	956	583
1991	7,782	1,600	2,213	3,087	821	602
1992	8,435	1,617	2,202	3,060	769	539
1993	8,800	1,683	2,140	3,164	705	435

a Awarded by chemistry departments offering an ACS-approved bachelor's level program.
b Chemical engineering departments are not required to report their degrees to ACS, so the number doing so varies from year to year. **Source:** ACS Committee on Professional Training

For many chemical companies, 1993 was a profitable year and 1994 is shaping up to be another one. That, in a nutshell, seems to be what's allowing them to cautiously step up their hiring. In addition, the downsizings that have been widespread among large companies of all types in the U.S. in the past few years seem to be easing off. Although new announcements of staff reductions at companies where chemists work are still being made, these announcements seem to be coming less frequently than they were a year or two ago. A recent survey by the American Management Association found that during the year that ended in June, 45% of major U.S. manufacturing companies reduced their work force, down from 56% that had done so two years earlier.

In the 1994 survey, manufacturing for the first time trailed all other major business sectors—such as financial services and retail trade—in the fraction of companies that had had work force reductions. More directly relevant to chemists are data from the Pharmaceutical Research & Manufacturers of America, which find that reductions totaling 8,130 jobs have been announced by its member companies so far in 1994, down from 23,000 for all of 1993.

"I think what I would call the batch process of terminations seems to be coming to an end," says Rohm and Haas' Burke. "You will continue to see people regularly leaving as companies continue to streamline, but I don't think they will be in the great numbers that we have seen, at least not in the chemical companies."

Dow Chemical expects to hire more chemists and chemical engineers in 1995 than it did in 1994, when the company was in the midst of a substantial downsizing. "We will be on campus recruiting for full-time hires at the Ph.D. level," Guthrie says. By far, the majority of chemists hired by Dow are at the Ph.D. level, he points out. The company will also be recruiting engineering undergraduates for summer intern and co-op programs. "We're keeping those programs very strong, and we will be recruiting quite actively for those individuals on a large number of campuses," Guthrie says. The program is so strong, he adds, that he expects all of Dow's bachelor-level engineering hiring to come from this group.

Union Carbide will be back on campuses recruiting this fall, after not doing so for 1994 graduates, according to Donald E. Gatewood, manager of recruitment and college relations. "As we did last year, we will be making full-time employment offers to the graduating seniors in our student employment program who meet our discipline, academic, and performance criteria. In addition, we will be recruiting on the campuses where we normally recruit," he says, looking primarily at the bachelor's level for chemical engineers. The company will also be aiming to hire more Ph.D. chemists than it did last year.

On the other hand, Rohm and Haas, which is currently in the midst of reducing its staff, will not be doing much hiring of new graduates this year. "We are trying to deal with our restructuring through internal placements," Burke says. "It's just not an appropriate climate to bring people in from the outside when there's a high level of anxiety [among staff members]."

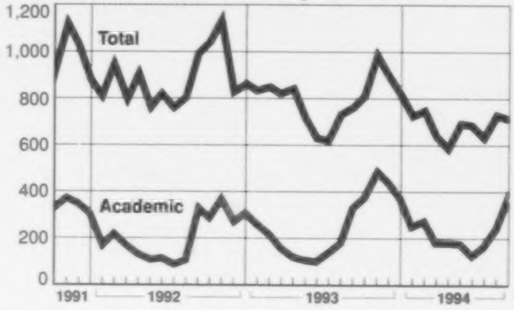
"We will definitely be doing a reasonable amount of hiring of Ph.D. chemists, as we did last year," says Procter & Gamble's Shulman. The company's hiring will be up this year for bachelor's and master's level chemists, as well, he adds.

Although by far the majority of people contacted by C&EN thought the employment picture for 1995 looked better than that for 1994, some were less sanguine. "My impression so far is that we still have a reduced number of [company recruiters] coming through," says Kenneth N. Raymond, chemistry department chairman at the University of California, Berkeley. Last year, Raymond says, some recruiters came on what he describes as "courtesy calls, really, just to keep in touch, not hiring anybody." As for this year, he says, "So far I don't see any dramatic improvement." Nor does Cornell's Ganem. "We are concerned that the employment picture for Ph.D.s looks tighter and more limited than it did last year," he says, "although I'm actually fairly optimistic that our department will do fairly well in placing people." At Texas A&M, too, recruiting visits are expected to be "less than or equal to" last year's levels, Harding says. "I would not expect more."

Mary L. Funke, head of ACS's Department of Career Services, says: "Employers are always seeking talent and so are interviewing. But actual hiring is pretty much the same as last year." Funke bases her assessment in part on activity at ACS's most recent National Employment Clearing House, held in conjunction with the ACS national meeting in August in Washington, D.C. Late summer meetings and those in northeastern cities always draw the largest numbers of job seekers to the clearinghouse, points out Anjalika Silva, staff associate responsible for the National Employment Clearing House, and the August meeting was no exception, with a record 1,505 candidates on site looking for jobs. Only 125 employer organizations registered to interview them, down from 139 at the spring 1994 meeting in San Diego and from 143 the previous August in Chicago. "Although there were fewer employers at the Washington meeting, the number of interviews was up from the spring meeting," Silva says.

C&EN's help-wanted ads give no clear sign of hiring recovery

Volume of "positions open" advertising, column-inches[a]



[a] Column-inches published during consecutive periods of four weeks each.

The most reasonable base for comparing activity at the recent clearinghouse, however, is probably the August 1992 national meeting, which was also held in Washington. Compared with that meeting, the most recent clearinghouse had 30% more job candidates interviewing with 25% fewer companies. Actual interviews were down 41% from two years ago and the number of jobs posted was down 38%. Moreover, Silva says, the mood at the most recent clearinghouse was decidedly downbeat. "What you hear from the candidates is that the job situation is bad," she says. "They are finding it difficult to get a job. And from the point of view of the employers, we find that some of them do come and interview, but they are not exactly ready to hire. They are kind of testing. There are some who have actual jobs, but there are others who are just keeping in touch."

This past summer, ACS's Department of Career Services conducted extensive interviews with more than 100 employers of chemical professionals including corporate vice presidents of R&D, division directors, company presidents, and chairmen of chemistry departments at universities. The purpose was to identify trends in technology and in the economic climate that will affect the chemical workplace over the next few years. Interviewers also asked about hiring plans for 1995 and beyond.

Although the full report of the study will not be completed until later this year, some things can already be gleaned from it. The study found, for example, that the hiring plans of companies vary greatly depending on company size. Companies with 500 or fewer employees were anticipating an increase in hiring, while large companies, with more than 10,000 employees, expected to maintain or decrease staff size. Most of the people interviewed said that the downsizings among employers of chemists are mostly over. And even those companies that plan to hold staff size steady or to decrease it will be doing some hiring for replacement or to obtain a different mix of skills among employees.

Most of the small companies included in the study were optimistic about the future. They are hiring now and plan to continue to do so, with a typical company planning to increase staff by 10 to 20% over the next several years. However, because the companies themselves are small, a 20% increase may mean only five or six more people. Most of the hiring at these small companies is for B.S. chemists, preferably with a few year's work experience. Such people need less on-the-job training than new graduates. The small companies are looking for broadly based generalists to help run their businesses. They need entrepreneurs and people who can tackle a broad base of challenges.

Some medium-sized companies in the survey were not planning to expand in the next few years; others expected growth of as much as 5%. None was expecting to decrease staff. These companies are hiring chemists at all degree levels, as well as chemical engineers. The B.S. chemists are mainly being hired as technicians and the Ph.D.s mostly for R&D.

The relative strength of smaller companies as employers of chemists has been apparent in the job market for several years, and many people contacted by C&EN report that there are very promising opportunities for chemists to be found there. For example, Dennis C. Liotta, chemistry department chairman at Emory University in Atlanta, says small companies that are just getting started are a student's "best option right now because there are so many of them around. They proliferate."

In addition, he says: "If you go into a startup company, especially a relatively new one, you have an opportunity and a degree of visibility that are tremendous compared with a traditional chemical or pharmaceutical company. You may be one of 20 scientists, as opposed to one of 400 scientists [in a larger company]. And if you go in at the ground floor, your [employment] package will probably include stock options. So if the company is sucessful, you can do very, very well financially, and you can do very well professionally. If the company is unsuccessful, you still probably will have five year's worth of good experience.

"Many times in a small company, you have to be more versatile, more diversified in the things you do, and for many people, that's attractive. I think someone who works for a startup company for five years probably has good training and probably has at least as good a chance of getting another job as anyone else. If the company is successful, they probably get promoted much more rapidly than they would in a large company, and they get much better financial rewards."

Rohm and Haas' Burke offers another reason why chemistry Ph.D.s and postdocs may find themselves well suited for taking jobs at small companies: The "culture" of these companies, he says, is very like that of academic research. "The typical research professor is an entrepreneur," Burke says. "He or she goes out and raises capital—that is to say, applies for grants—and then employs people on different kinds of projects that are, in some cases, speculative; certainly all of them are fairly daring. There's a mentality that the postdocs and the graduate students absorb that makes their going to these smaller companies a fairly easy transition."

However, Burke and others point out that it takes a great many small companies, each hiring only three or four chemists a year, to make much of a dent in overall chemical employment. In fact, MIT's Sibley points out that last year his department had more company representatives come to interview students than ever before, but, because a lot of them were from smaller companies, the overall number of jobs they were offering was actually smaller than usual. He expects the same situation this year.

How academic employment is shaping up for 1995 is much harder to tell. A spot check at 10 chemistry departments around the country finds much the same range of sentiments that have been heard for several years. Almost all chemistry departments contacted by C&EN were hoping to fill at least one position in the coming year. The reasons for that are clear: Undergraduate chemistry enrollments are rising and many faculty are reaching retirement age. Several departments say they have still not found the candidate they want to fill positions that have been open since last year, despite receiving several hundred applications for each opening.

Yet many chairmen still report that academic employment is very tight. At the University of California, San Diego, for example, nine chemistry faculty will be retiring this year, thanks to a particularly generous retirement package the university is offering in an attempt to reduce its overall staff. That's roughly one fifth of the entire department, yet the department expects to be able to replace only one or two of them, despite increasing undergraduate enrollments.

"Private universities are [also] having to tighten up," says Jeremy K. Burdett, chemistry department chairman at the University of Chicago. "Our chemistry faculty almost certainly will shrink. . . . We're recruiting, but we are not going to be able to recruit as aggressively as we should be to make up for retirements and losses."

But the picture looks better at some departments. "During these difficult economic times, we've actually been able to maintain an influx of new young faculty," says Joseph L. Templeton, chairman of the chemistry department at the University of North Carolina, Chapel Hill. "We got a 6% salary increase for faculty this year, after years of zero and 1% increases, so that was a big improvement. But while we were getting that, there were cuts to the College of Arts & Sciences for supplies." He adds: "I think the number of academic openings is holding constant or increasing."

MIT's Sibley doesn't think so. "Some of our very good students and postdocs are ending up in schools that are good schools but are not the strong research universities where I think most of our people, if they want to go into academic work, want to end up," he says. "These people would have had different choices 10 years ago."

One avenue that some chemistry Ph.D.s seem to be taking is to accept faculty positions at smaller, non-Ph.D.-granting universities or colleges instead of heading for a postdoc. These are jobs that involve supervising student research as well as teaching. Several department chairmen reported 1994 graduates who had opted for this route. Emory's Liotta speculates that students are attracted to such positions not because of the scarcity of faculty postions at Ph.D.-granting universities, but rather because the prospect of becoming a junior faculty member at such universities has become unappealing. "With the funding situation as tight as it is, and students knowing that there's essentially a direct link between getting funded and getting tenure [at a major research university], I think a lot of people are reluctant to get into the fray," he says. □

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CHEMICAL & ENGINEERING NEWS

C&EN

OCTOBER 31, 1994

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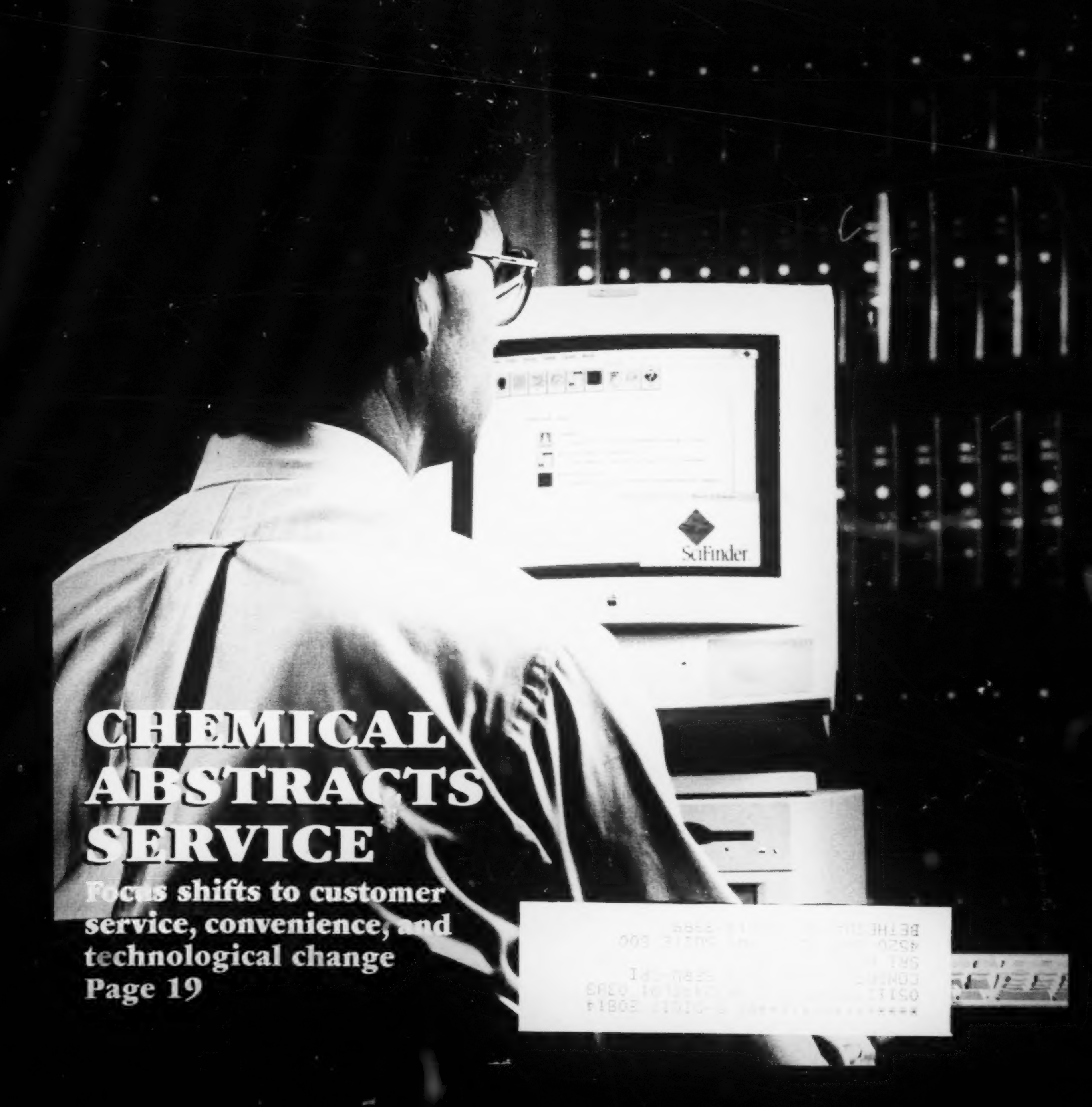

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C&EN

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- Carnegie Mellon chemists synthesize a "molecular photonic wire" that absorbs a photon of light at one end and emits a different photon at the other end. Page 5
- Preparations for National Chemistry Week (Nov. 6–12) intensify, including several projects focusing on chemistry education and careers. Page 5
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1155—16th St., N.W., Washington, D.C. 20036
Editor: Michael Heylin (202) 872-4501
Managing Editor: Madeleine Jacobs
Assistant Managing Editors: Rudy M. Baum, Ernest L. Carpenter, Janice R. Long, Rebecca L. Rawls, William J. Storck
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News Bureaus: Northeast: (908) 906-8300 Ann M. Thayer (Head), Elisabeth Kirschner (Assistant Editor), George Peaff (Assistant Editor), Rachel Eskenazi (Administrative Assistant). Houston: (713) 558-2912 Susan J. Ainsworth (Head). Washington: (202) 872-4495 David J. Hanson (Head), West Coast: (206) 517-5034 Deborah L. Illman (Associate Editor). London: (01) 44 81 870-6884 Patricia Layman (Senior Editor), (01) 44 256-811052 Michael Freemantle (Senior Editor)
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LETTERS

Exceeding Earth's capacity

The ideas of Bryan J. Cook (C&EN, May 16, page 5) and Frank A. Anderson (C&EN, June 13, page 4) deserve elaboration, particularly one social dilemma created by the continuing application of science-backed technology. I refer to the decrease in the carrying capacity of planet Earth for people that occurs each time there is an increase in human technological activity. This interconnectedness has long been unrecognized or ignored. I regret that my 40-year career in chemical science and technology produced a number of conventional economic evaluation studies in which this carrying capacity factor was never recognized by the existing myopic economic system. The negative social impact, veiled from my view then, is clear to me now.

Carrying capacity could be ignored if it were larger than the current global population size. Unfortunately, it is smaller. Numerous scholars now insist that population exceeds carrying capacity. My own studies, based on waste disposal capabilities, suggest that population currently exceeds carrying capacity by a factor of between 10 and 40. It is this excess that drives the social changes Cook attributes to science. The larger that excess becomes, the more rapid are the changes. While technology has certainly decreased carrying capacity in years past and continues to do so in the present, responsibility for the exploding population, the numerator in the ratio, belongs elsewhere.

As the demand for sustainability increases, the chemical industry will need to come to terms with this scenario and with the industrial contribution to the denominator in this ratio.

Carlyle Herrick
Alplaus, N.Y.

Transfermium wars

Concerned readers should not overreact to the news of the recommendations by the International Union of Pure & Applied Chemistry's (IUPAC) Commission on Nomenclature of Inorganic Chemistry (CNIC) concerning new names for the transfermium elements (C&EN, Oct. 10, page 4). Their unwise suggestions have no procedural power of enforcement behind them. I state that without any authority, in parallel with CNIC's lack of authority to impose the naming sequence for elements 104–109. All that has been done with this strange idea and imprudent treatment of the uncontested discoverers of seaborgium is to embarrass IUPAC.

For more than a decade, IUPAC has been incapable of resolving the conflict of discovery of elements 104 and 105 to the satisfaction of the interested chemical community. They participated in a flawed study to settle the dispute and issued a recommendation in late 1992 that was received with critical disclaim. IUPAC did not place heavy-element nuclear chemistry experts on the study panel (the transfermium working group) as they were charged to do, nor did they conduct their investigation in an iterative protocol, as they were charged to do, and which would seem logical and necessary. They did permit the Russian contestants for element 104 to do a total about-face following an unprecedented reanalysis of old data, and to contradict the Russians' own original firm conclusions about what they had done. The transfermium working group's judgment was arguably motivated by a fervent desire to do everything possible to coerce a compromise. Nevertheless, there was no dispute over element 106.

Because of the controversy surrounding the way in which the transfermium working group focused their labors, a movement was started to try to prevent any formal recommendations from being made until the review panel completed their investigation properly so that the endorsement on discovery claims at least had the appearance of being merited by the facts. This was not forthcoming.

The ACS Committee on Nomenclature then officially adopted the following names for use in the U.S. and forwarded these as a recommendation to IUPAC; 104 = rutherfordium, 105 = hahnium, 107 = nielsbohrium, 108 = hassium, and 109 = meitnerium. (Attention textbook publishers, these are the names that will be used in the U.S.) The latter three elements had been justifiably credited for the most part to German researchers, and those names are the ones they had suggested.

Element 106 was not included because its discovery had not yet been confirmed by independent means. This verification was recently attained. The original discoverer proposed the name seaborgium at the

Continued on page 32

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supply of purified terephthalic acid (PTA), a key raw material in the production of polyester, will serve as a limiting factor in demand for fiber-grade ethylene glycol in 1995. "However, in 1996, hang on to your hat," he says. "Lots of PTA capacity will be coming on stream, opening the floodgates of polyester production and creating a potential shortage of glycol."

Recognizing this trend, at least two producers are gearing up for capacity expansions in that time frame. Occidental Chemical is evaluating significant expansions at its Bayport and Beaumont, Tex., facilities to be on line within two to three years. More significantly, Union Carbide is teaming up with Petrochemical Industries Co. of Kuwait in a joint venture to build and operate a petrochemicals complex in Kuwait that will include a 770 million-lb-per-year ethylene glycol plant. Like the Red Deer plant in Canada, this facility will have an advantageous feedstock position and will be well positioned to serve the Asia-Pacific region.

Still, Rightler predicts that these expansions "may not be large enough to meet demand." Fortuitously, Carbide's forecast paints the same picture. "By the time we get to 1996, especially late 1996, we think the ethylene glycol market will again be tight. In fact, we may wish that the Kuwait plant came on earlier than scheduled." ☐

Europe looks to 'new perspectives' in polymers

"Profiting from new perspectives" was the theme for the annual meeting of ECMRA, the business research and planning association in Europe, earlier this month in Leipzig, Germany. The theme foretold what has become clear as the year draws to a close: business is picking up, and now is the time for concentrating on what's new, rather than gloomy rehashings of such matters as overcapacity and low profitability.

High on the agenda were new technologies for making polyethylene and environmental concerns for the industry—including an encouraging look at second-generation biopolymers.

According to David Oxley, a director at the London office of consultants ChemSystems, global demand for polyethylene of all types now amounts to about 37 million metric tons per year. Of that amount, about 15 million metric tons each is accounted for by low-density polyethylene (LDPE), made at high pressure, and high-density polyethylene (HDPE), made at relatively low pressure. Linear low-density polyethylene (LLDPE), also made at relatively low pressure, makes up the remaining 7 million metric tons per year.

However, the global market for LLDPE is expected to reach 12 million metric tons by 2000. Demand for LDPE will rise only modestly—to about 17 million metric tons—as it faces competition from LLDPE, which has gained market share through lower prices. HDPE, on the other hand, will continue to experience solid growth to 19 million metric tons per year by 2000.

In addition, changing technology for making polyethylenes will have a significant impact on the industry, says Oxley.

Among the new processes for making or modifying polyethylenes, Oxley says, are:

- Metallocene catalysts, which enable a producer to "tailor a polyethylene molecule more accurately. That is true for polyethylene or polypropylene but is particularly important for LLDPE."
- Bimodal/broad molecular weight LLDPEs, which are easier to process than earlier LLDPEs. Because LLDPE is more difficult to process than LDPE, producers of LLDPE have had to accept lower prices to build market share. Now they will be able to justify asking for the same price for LLDPE as for LDPE.
- Superhexene LLDPE, which features new comonomers for improved performance. Although very costly now, prices are expected to come down as South Africa's Sasol and Czech producers become serious suppliers of comonomer α-olefins.

German recycling fees are highest for plastics

	$ per kg
Plastics	$1.97
Composites	1.40
Beverage cartons	1.13
Aluminum	1.00
Tinplate	0.37
Paper	0.33
Natural materials	0.13
Glass	0.10

Source: Duales System Deutschland

On metallocene catalysts alone, more than 350 patents were issued or were pending by the beginning of this year, Oxley says. High on the list, with about 80 patents, was Mitsui Toatsu Chemicals; with about 50 patents each were Hoechst, Mitsui Petrochemical, and Exxon; at about 20 each were BASF, Fina, Idemitsu, and Mitsubishi Petrochemical. Dow Chemical, Showa Denko, Phillips, British Petroleum, Chisso, and Mobil all had about 10 patents each; and Tosoh held fewer than 10. Curiously, Union Carbide and Himont—major players in the polyethylene and polypropylene fields—had none.

Oxley predicts that by 2010, the demand for metallocene-produced polyethylene will be 2.5 million metric tons per year. Bimodal/broad molecular weight LLDPE will find much larger demand—about 3.3 million metric tons per year. He expects Europe to dominate in this sector. Polyethylenes containing higher α-olefin comonomers (for example, 1-octene) will have demand of about 1.2 million metric tons per year.

"The new developments in catalysts allow much simpler plants to make the sophisticated polymers, and this will cut the cost and widen the supply base. Whether this is a good thing for corporate profitability remains to be seen," he adds.

For one thing, companies have invested a great deal of money in their research—money that ultimately will have to be recouped. For example, according to ChemSystems' estimates, from 1983 to 1993, some $2 billion has been spent on R&D for second-generation polyethylenes, half of that on metallocene research alone. Moreover, more than $1 billion in new capital expenditures has been approved since the beginning of 1993 for second-generation polyethylenes. "All this [expense] has to be paid for by licensing or by profit margins," he notes.

On a much more modest basis, a second generation of biodegradable polymers is being developed, says Luigi Marini, business manager for these materials at Italy's Novamont, a sister company of Montecatini. Applications vary for the polymers, which are available as films, fibers, and foams.

More than a dozen companies are active in the field, with products at various stages of commercial development. For example, in the field of starch-polyester polymers, Novamont has capacity of 4,000 metric tons per year; Chisso, in Japan, has a plant under construction; and in the U.S., National Starch and Enpac have operations of undisclosed capacity. Ems-Chemie, Melitta, and Biopack—all European companies—are in the pilot-plant stage with their starch-based polymers.

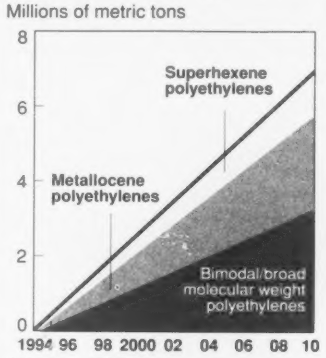
The synthetic polymer side is somewhat more advanced. Union Carbide in the U.S. and Daicel in Japan both have capacities of at least 4,000 metric tons per year of polycaprolactone. Cargill in the U.S. has capacity of 4,500 metric tons per year of polylactic acid. The U.K.'s Zeneca can make up to 600 metric tons per year of its polyhydroxy butyrate-valerate, and Japan's Showa Denko has more than 1,000 metric tons per year of capacity for its polymer made of butanediol and succinic acid.

The important point about these materials, contends Marini, is that biodegradable materials "must be seen in competition with materials like cardboard, paper, glass, and wood—not with other polymers. There are different requirements" as the polymers vie for markets in packaging or in consumer goods that would otherwise wind up in landfills. The largest proportion of waste goes to landfills—some 60%, he says, with another 30% incinerated and 10% recycled. A goal of the European Union (EU) is to reverse this situation by the end of the decade, to 10% for landfills, 35% for incineration with energy recovery, and 55% for recycling and composting.

Biodegradable polymers cannot compete directly with traditional polymers, but they can give a cost-effective solution to waste—a point even the environmental movement has begun to recognize, he suggests. "The "green" movement has been very much against the early generation of starch-polyethylene materials—and they were absolutely right. These materials do not biodegrade," Marini says. "They don't solve any problems."

Where composting is not feasible, recycling is becoming more and more important for European society. According to Edelgard Bially, a group leader with Duales System Deutschland (DSD), the organization responsible for recycling postconsumer packaging wastes in Germany, the average European citizen piles up about 770 lb of waste each year. Of that, packaging waste makes up 30% by weight and 50% by volume, one reason why packaging has become a priority target among German environmental officials.

Demand to rise most for bimodal polyethylenes



Source: ChemSystems

In June 1991, a German federal ordinance decreed that packaging material must be recycled: 50% of glass, tinplate, aluminum, paper and cardboard, composites, and plastics, each year until July 1995. From July 1995, the proportion that must be recycled rises to a minimum of 80%, Bially explains.

DSD runs its system on a cost-covering basis, with financing through license fees for use of its trademarked Green Dot on packaging that can be recycled. The license fee is paid by the product packager. At the beginning of October, DSD's licensing fee structure was changed to include volume as a pricing factor, in addition to weight and the material involved. The fee for glass packaging was dropped slightly—as was that for plastics, which fell from 3 deutsche marks (about $2.00) per kg to 2.95 deutsche marks per kg of waste packaging; the fee for plastics, however, remains the highest of all the packaging materials.

As Bially puts it, "Every system depends on the efforts of its participants," and German consumers have taken the concept of recycling to heart. In 1993, some 4.6 million metric tons of recyclable material were collected, 57% of the potential. Out of the amount collected, 3.9 million metric tons were sorted for recycling. In 1993, 15% less waste than in 1991 had to be disposed of, she says.

And despite the "villain" environmental image of plastic packaging, Bially notes that it actually provides one of DSD's major recycling successes. There have been at least two reasons: the controversial exports to other countries for recycling and the development and adoption of feedstock recycling—the thermal cracking of polymers back into reusable feedstocks.

Germany now has one commercial feedstock recycling operation, run by Veba Oil and Ruhrkohl Umwelt, with capacity of up to 50,000 metric tons per year, and scheduled for expansion to 140,000 metric tons next year. BASF has piloted a scheme with 15,000 metric tons per year of capacity, and it plans to have capacity of 200,000 to 300,000 metric tons as of 1996. That, Bially argues, is extraordinary, considering that when the ordinance was put into effect in 1991, "nobody was talking about feedstock recycling at all." Now, however, "if all the offered capacity comes on stream," says Bially, "we might even come into the situation that we could import waste plastics into Germany."

On the same day ECMRA was tackling the topic of recycling, the Association of Plastics Manufacturers in Europe (APME) was conducting a forum on the feedstock recycling technology being developed by a European consortium of plastics producers at a pilot plant in Grangemouth, Scotland. The consortium, consisting of BP Chemicals, DSM, Elf Atochem, EniChem, and Petrofina, is developing technology that uses a fluidized-bed thermal cracking process at relatively low pressures.

The pilot project, located on BP Chemicals' plant complex, is assessing the technology, as well as the operating costs and levels of investment required for its implementation. The consortium's objective is to take the technology up to the stage of conceptual design of a semicommercial demonstration plant, with capacity of 25,000 metric tons of mixed plastics waste per year. Total investment for such a plant is estimated at about $32 million. Following completion of the program, the results can be used or licensed by each member of the consortium.

Feedstock recycling, says Fred Mader, APME's deputy director, "will be able to increase total plastics waste recycling, but it must be developed as part of an integrated waste-management strategy."

Patricia Layman

OTA Report Links Research And Technology To Economic Development

■ ***Study raises concerns that research funded by federal government may be aiding foreign companies that invest in the U.S.***

Investments in research and development by large multinational enterprises have a direct impact on the competitiveness and international trade of nations. A new study of this relationship by the Congressional Office of Technology Assessment (OTA) raises concerns about the imbalance of these investments between the U.S. and its trading partners. Some policy changes are suggested to correct the situation.

OTA finds that despite recent trends toward internationalization of technology, most multinational enterprises develop their core technology in their country of origin. U.S.-based corporations, for example, conduct less than 13% of their manufacturing R&D abroad, and what data are available for European and Japanese companies indicate that they may conduct even smaller percentages of their R&D abroad than do U.S. firms.

The OTA analysis, the final of two studies on this issue, was requested by Sen. John D. Rockefeller IV (D.-W.Va.), chairman of the Commerce, Science & Transportation Subcommittee on Science, Technology & Space and one of the authors of the failed technology competitiveness act of 1994 (S. 4). Rockefeller was seeking information that would help U.S. policymakers understand how highly developed countries invest in other countries and how that affects the U.S. economy.

Rockefeller: U.S. taxpayers must benefit

"Congress must be sure that the technology programs supported by American taxpayers' dollars reap dividends for Americans—especially high-paying manufacturing jobs in the U.S.," Rockefeller said when releasing the report. "Examples of such programs include the National Institute of Standards & Technology's Advanced Technology Program in the Department of Commerce and the Defense Department's Technology Reinvestment Program."

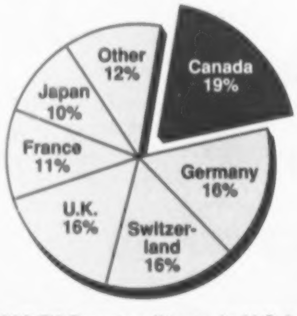
OTA suggests that Congress may wish to consider some sort of national benefit criteria to ensure that foreign-owned multinational companies that participate in these government-supported programs contribute directly to the U.S. technology base, not just indirectly through an affiliate. On average, OTA reports, such foreign-based companies contribute less to the U.S. technology base than do U.S.-based firms. However, establishing any such criteria would be difficult.

Foreign affiliate investment in R&D has increased substantially in recent years, from $4.5 billion in 1980 to $10.7 billion in 1992. More than half of the R&D spending was on manufacturing in three industries: chemicals, pharmaceuticals, and nonelectrical machinery. The most growth has been in pharmaceuticals. U.S. firms, on the other hand, increased their R&D investment in other nations from $4.3 billion to $8.4 billion during that same period. Principal manufacturing areas of concentration were machinery and transportation equipment. Usually this spending supports R&D by a company's own affiliates.

OTA reports that a factor significantly affecting the technology base is the tendency of Japanese firms to spend more on technology development as a percentage of their nation's gross domestic product than do their U.S. or European counterparts. Between 1981 and 1993, R&D expenditures by industries in Japan grew at an average rate of 8%. The average growth rate for U.S. firms was 3.9%. One reason cited for this difference is that the U.S. devotes much of its R&D budget to defense-related development, while other nations, especially Japan and Germany, are oriented more toward commercial technologies.

The report also analyzes other aspects of the U.S. trade deficit with Japan, a condition that's expected to continue for years to come. Part of the reason for the continuing deficit, says OTA, is that in-

Canada leads foreign R&D investment in U.S.



1992 R&D expenditures in U.S. by foreign companies = $10.7 billion

Source: Office of Technology Assessment vestment in the U.S. by large Japanese multinational firms exceeded U.S. investment in Japan by a factor of three to one. OTA reports that while global foreign investment expanded dramatically in the 1980s and 1990s, U.S. direct investment in Japan failed to keep pace with the trend.

Among the reasons cited for this difference in investment is that long-term capital markets in Germany and Japan are more patient in waiting for a return on their investment. Also, the distinctive cross-shareholding and corporate banking relationships that shape business strategies in Japan and European nations are not as open to U.S. firms.

OTA identifies three policy strategies the U.S. might consider in responding to what it sees as international asymmetries in the global trade, investment, and other barriers to comparable market access. The first involves seeking to expand existing multilateral trade agreements to include issues such as direct foreign investment and restrictive business practices, some of which are included in the recent trade treaty negotiated by the General Agreement on Tariffs & Trade (GATT), which Congress will take up in late November.

Second, OTA concludes that the U.S. might adopt a two-tiered policy regime that grants equal footing to domestic companies and foreign affiliate companies when comparable market access exists, but that places conditions on equal treatment in response to enduring formal or informal market barriers in the company's home nation. Third, the U.S. could augment a broad multilateral strategy with domestic measures designed to improve U.S. technological capabilities and reform U.S. trade and investment policies to meet the demands of increasingly global commerce.

Rockefeller thought the U.S. was moving along the right path last year with his competitiveness legislation, but the bill got derailed in conference committee at the end of Congress this year. He also supports passage this year of the legislation needed to implement GATT, which would help remove trade barriers and open markets.

David Hanson

NIH unit reorganizes research support programs

The National Institute of General Medical Sciences (NIGMS), the largest single source of chemistry funding within the National Institutes of Health, has reorganized to reflect the increasingly interdisciplinary nature of the research it supports. The changes are also meant to streamline its operations in accord with the Clinton Administration's push to reinvent government.

NIGMS's mission is much broader than those of the other NIH institutes, which specialize in specific diseases or organs. NIGMS, in contrast, supports the basic science underlying health-related research. The institute also leads NIH's activities aimed at increasing the number of minority scientists in biomedical research. NIGMS staff conducts no research itself, so the bulk of its budget—approximately $900 million for fiscal 1995—goes directly to universities and other research institutions.

In the most significant change, the institute has rearranged its four program branches—Cellular & Molecular Basis of Disease, Genetics, Biophysics & Physiological Sciences, and Pharmacology & Biorelated Chemistry—into three divisions: Cell Biology & Biophysics, Genetics & Developmental Biology, and Pharmacology, Physiology & Biological Chemistry. Also, the Minority Opportunities in Research programs have been designated a division.

"The reorganization reflects the increasingly interdisciplinary nature of the research funded by NIGMS," says Marvin Cassman, the institute's acting director. "By refining the distribution and balance of scientific areas among the divisions, we will improve the institute's ability to promote and support the most innovative basic research of the future."

The changes should not be noticeable to scientists supported by NIGMS, however. "We are not diminishing support for any field," says Warren Jones, chief of the biochemistry and biorelated branch in the new Division of Pharmacology, Physiology & Biological Chemistry. The reorganization is not meant to redirect the emphasis of NIGMS's grant portfolio, but to streamline its administration.

NIGMS, like other NIH units and the federal government in general, is faced with complying with the Clinton Administration's reinventing government goal of reducing work force rolls. The new structure is designed to help the institute administer an ever increasing number of grant applications with a slightly smaller staff.

NIGMS also has moved to the NIH campus in Bethesda, Md., from quarters in a rented building a few miles away. The entire institute staff is now located in the new William H. Natcher Building on the main campus.

Pamela Zurer

Chemistry support is spread through three NIGMS divisions

Division of Cell Biology & Biophysics
- **Analytical and separation techniques**
- **Bioengineering**
- **Biomedical instrumentation**
- **Cell organization, motility, and division**
- **Lipid biochemistry**
- **Membrane structure and function**
- **Molecular biophysics**
- **Spectroscopic techniques**
- **Structural biology**

Division of Genetics & Developmental Biology
- **Cell growth and differentiation**
- **Chromosomal organization and mechanics**
- **Control of gene expression**
- **Developmental genetics and cell biology**
- **Extrachromosomal inheritance**
- **Human medical genetics**
- **Mechanisms of mutagenesis**
- **Molecular immunobiology**
- **Neurogenetics and the genetics of behavior**
- **Population genetics**
- **Replication, recombination, and repair of genes**

Division of Pharmacology, Physiology & Biological Chemistry
- **Anesthesiology**
- **Biochemistry**
- **Bioenergetics**
- **Bio-organic and bioinorganic chemistry**
- **Biotechnology**
- **Glycoconjugates**
- **Medicinal chemistry**
- **Pharmacology**
- **Physiology**
- **Synthetic chemistry**
- **Trauma and burn injury**